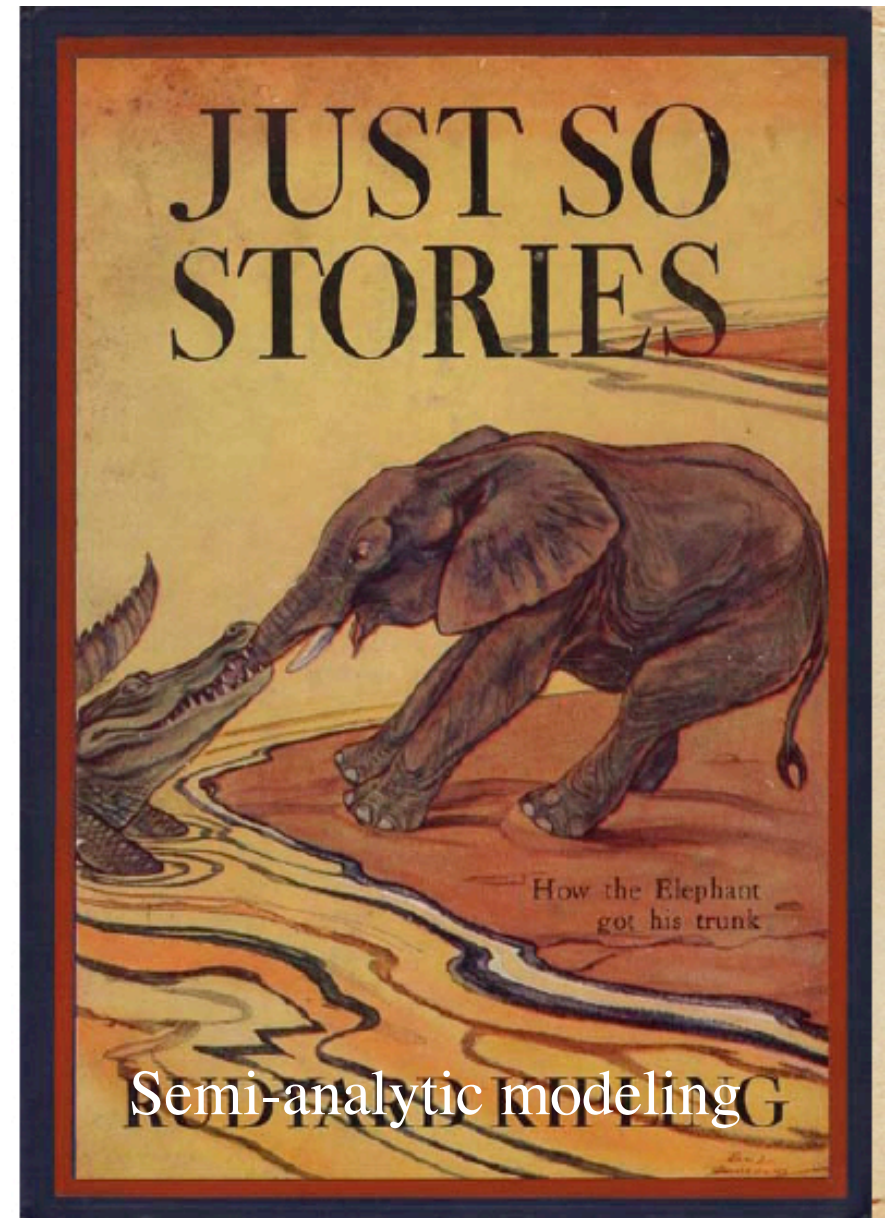


# *How the Observable Universe Came to Be*

- Dark matter evolution in the universe now understood
  - **it is not at all understood how ‘baryonic structures’ (galaxies, groups, clusters) form.**
- For models to fit the data additional physics (beyond gravity and hydrodynamics) is required (heating, cooling, mass and metal injection, gas motions etc)
- Up until now this has been parameterized in ‘semi-analytic’ models - **just so stories**
- *The critical problem in all of astrophysics is to put physics into these stories*
- **Ideas and material stolen from M. Begelman, T. J. Cox, D. Croton, T. DiMatteo, I. George, C. Martin, J. Ostriker, V. Springel, C. Steidel, S. White...**



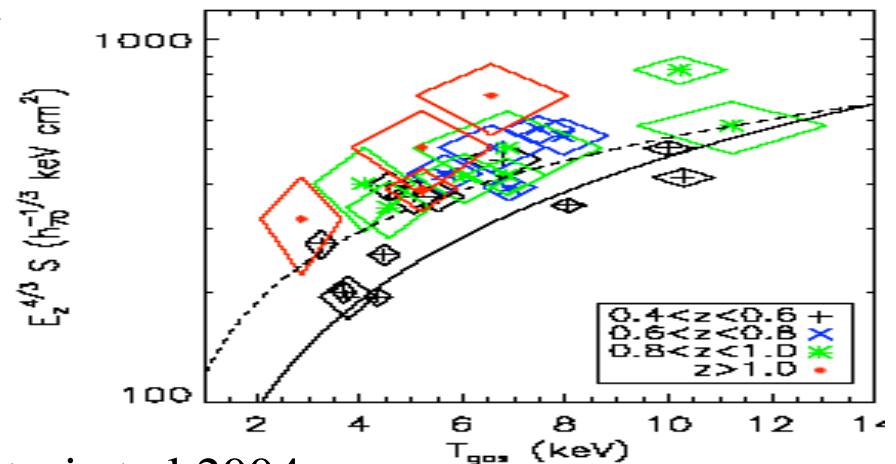
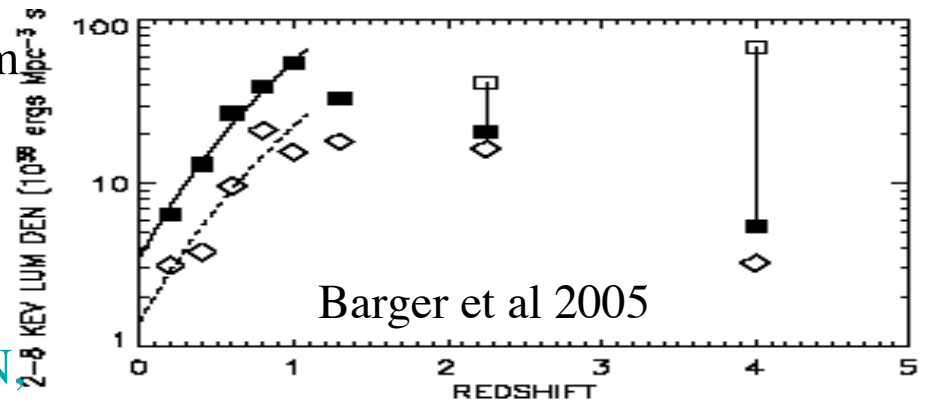
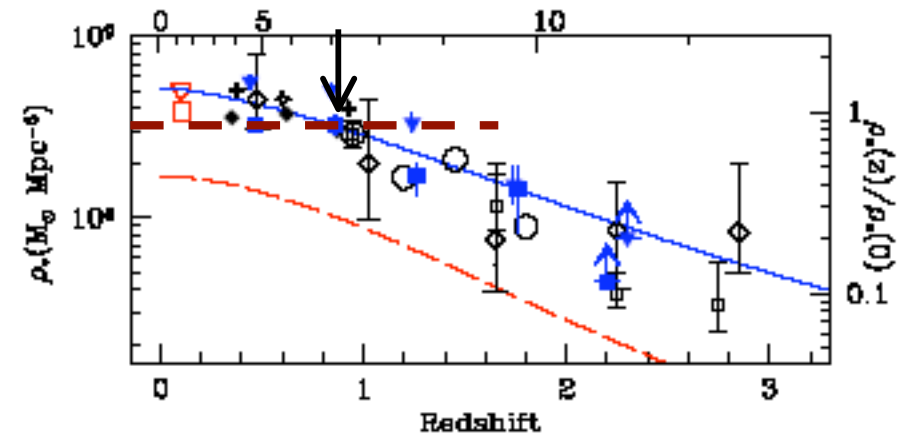
Semi-analytic modeling

# How the universe came to be the way it is

## What has changed in the last 4 years

- We now know (Barger et al 2004, Heavens et al 2004, Conselice et al 2004, lots more) that
  - at  $z > 1.5$  the universe is very different from today
  - Most stars in the universe formed from  $0.3 < z < 1.5$
  - The epoch of black holes is  $z \sim 1$
  - Cluster evolution is doing something quite interesting at  $z \sim 1$
- Con-X can study the  $z \sim 1$  universe (AGN clusters and galaxy/star formation) in great detail

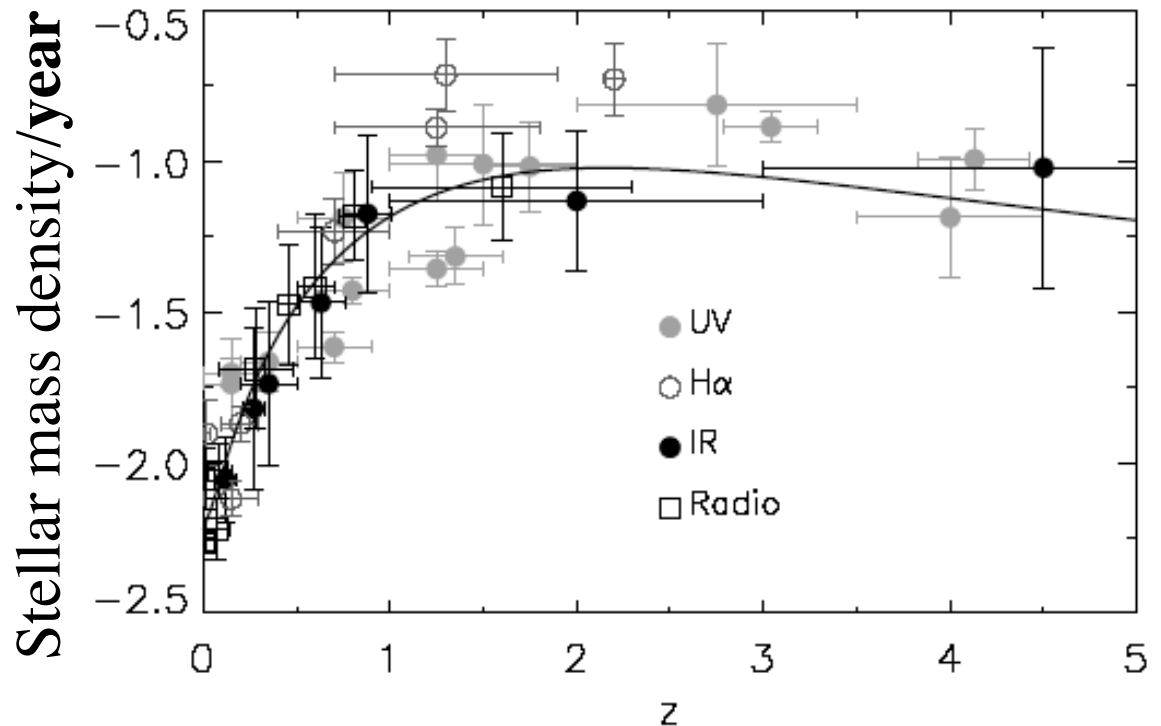
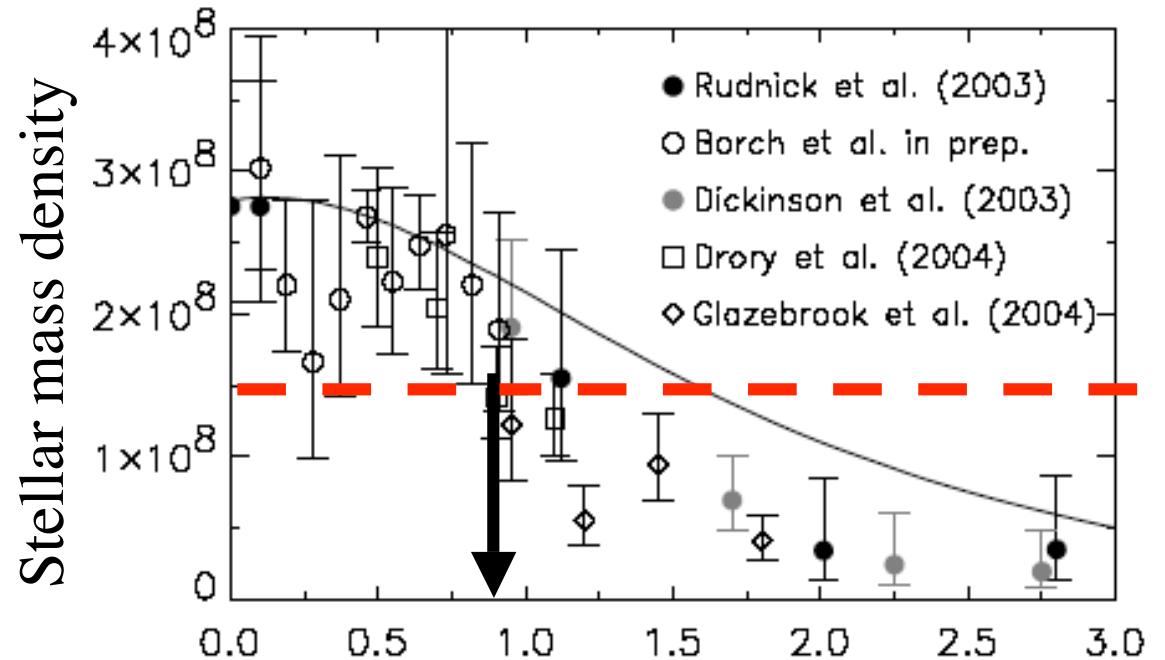
Only x-ray astronomy can measure how where and when most of the energy that controlled how universe formed was produced



Ettori et al 2004

## When did the stars form?

- Recent work (e.g Bell et al 2004, Heavens et al 2004, Rudnick et al 2003) shows that  **$\sim 1/2$  of all stars form at  $z < 1$**
- Integration of the SFR rate would give the 1/2 mass redshift at  $z \sim 1.5$
- This agrees with the new x-ray data for AGN reinforcing the co-evolution of black holes and galaxies

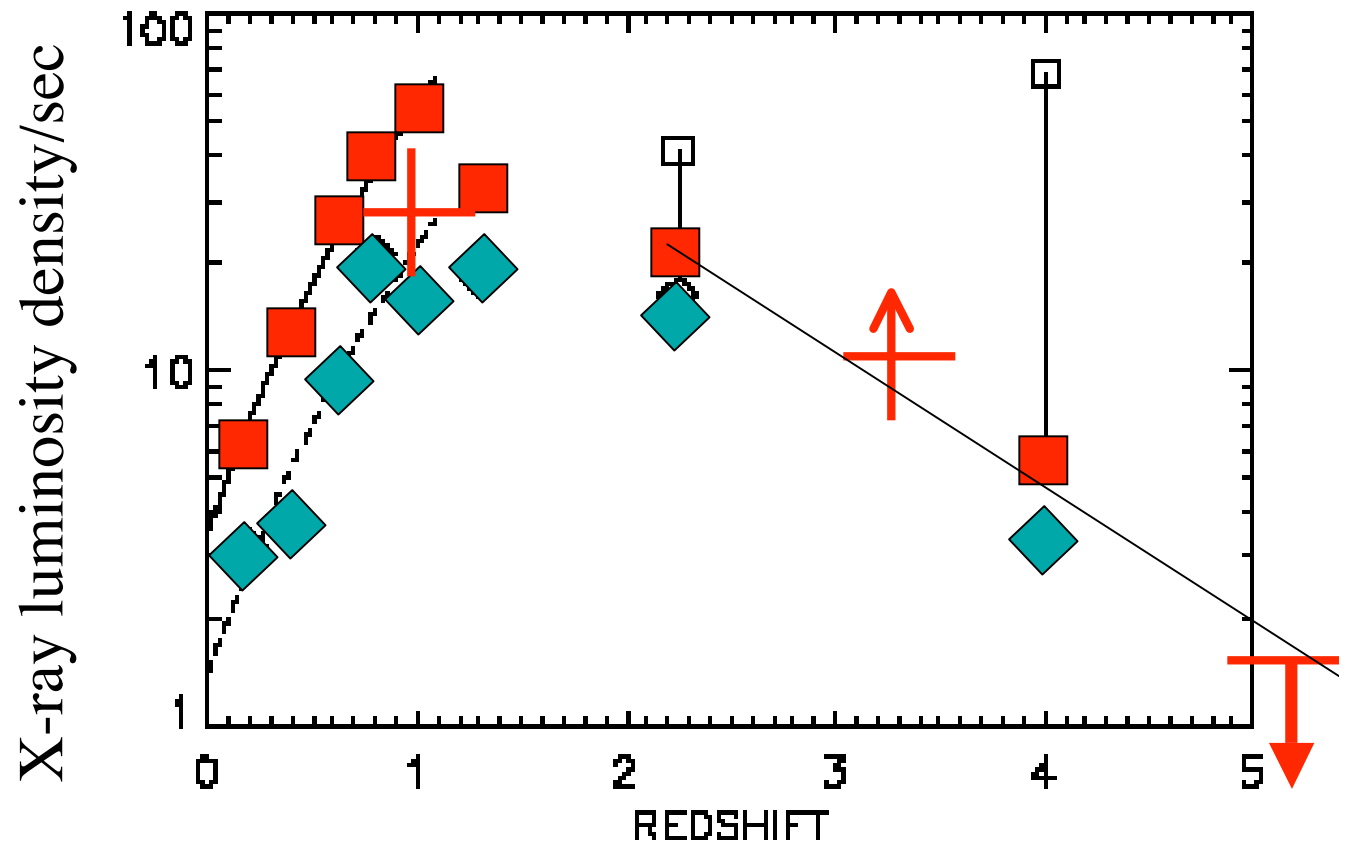


# The AGN History of Universe- X-ray Selected AGN

- Even including upper limits there is less energy emitting per unit volume at  $z > 1$

Barger et al 2005

**X-ray selected AGN have a similar evolution to total star formation rate at  $z < 2$**

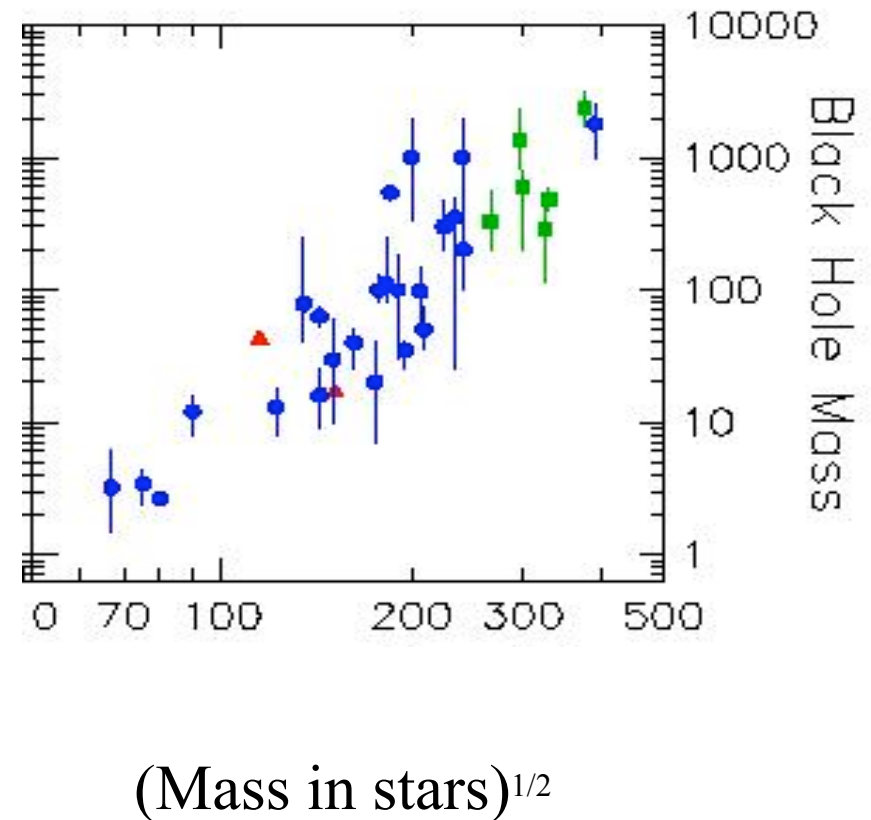
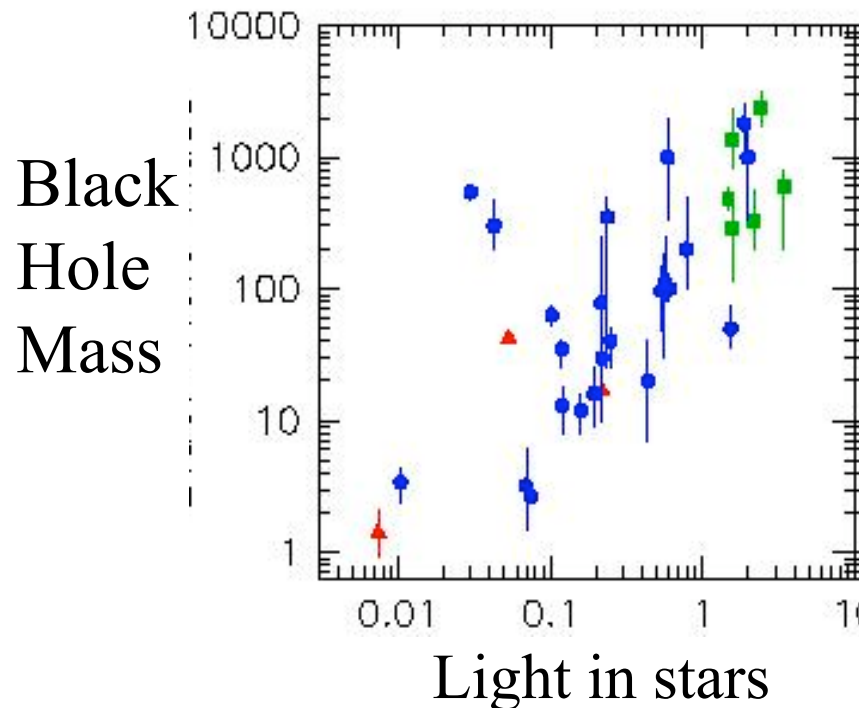


◆ type I AGN, ■ all objects

Open box- assigning all objects without a redshift to redshift bin

## Strong relationship between galaxy and its central massive black hole

- The mass of stars in the galaxy is strongly correlated with the mass of the central black hole
- Black holes have had a strong influence on galaxy formation and evolution



## X-ray Astronomy in the Next Decade

### the main science themes and

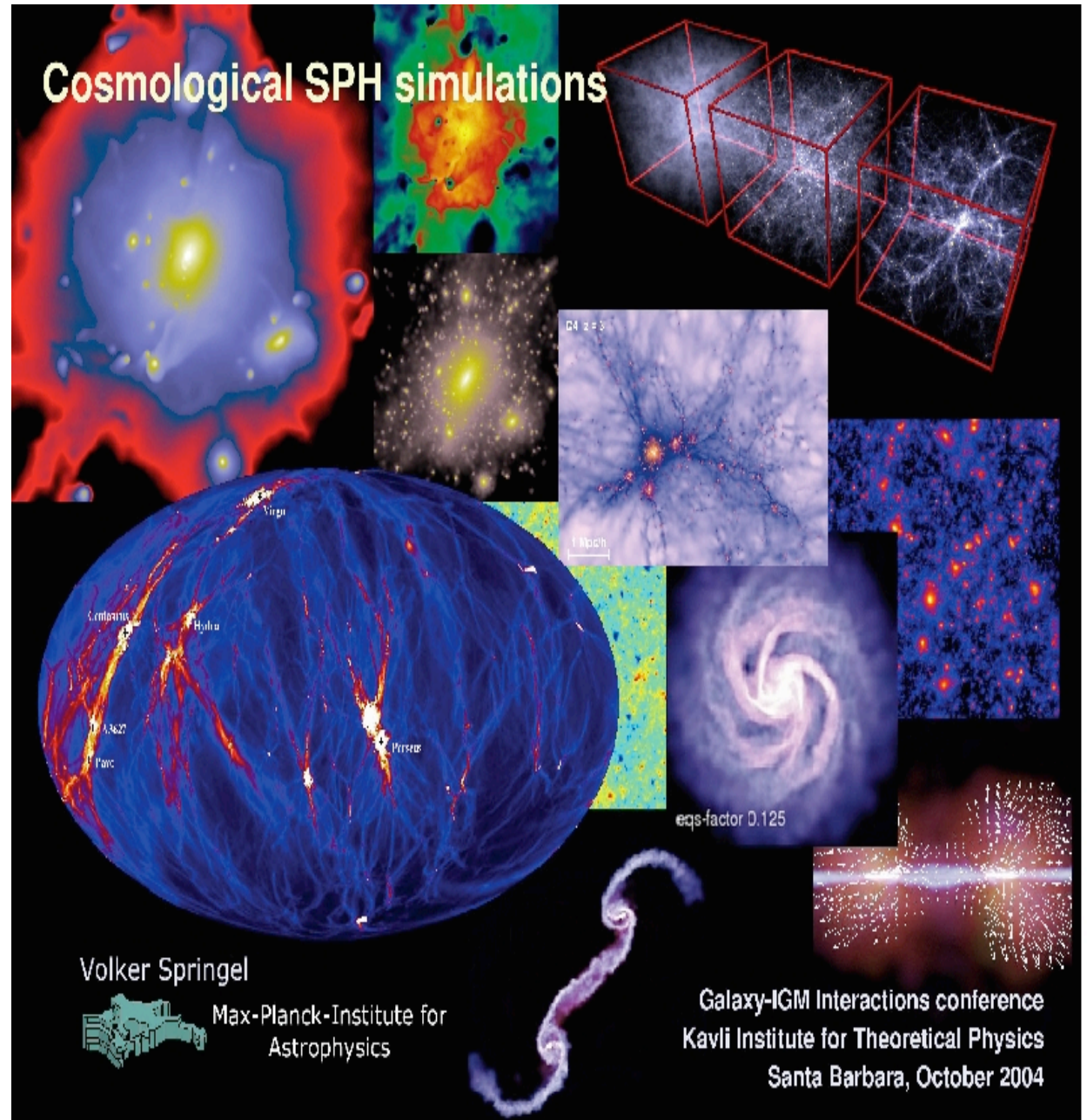
- Cosmology  
nature of dark matter  
cosmic geometry  
large scale structure
- Galaxy formation and evolution-
- Extreme environments of astrophysics  
massive black holes  
end stages of stellar evolution

### the role of x-ray observations

- Amount of and distribution of dark matter in “spherical systems”
- How do AGN influence their galaxy and how does this change with cosmic time
- direct observation of star formation rates, chemical abundances and galactic winds **over a wide range of redshifts**
- What is the cause of the ecology of the ISM/IGM- interaction of SN with ISM, winds, outflows, enrichment
- What is the origin of the “entropy problem” in groups and how does it influence structure formation

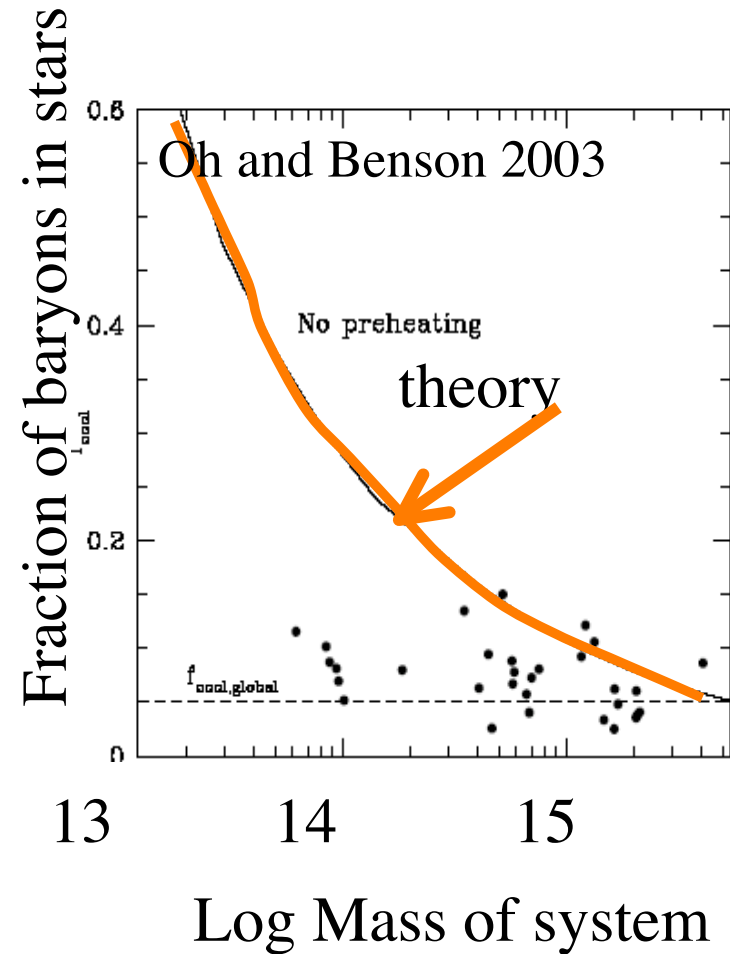
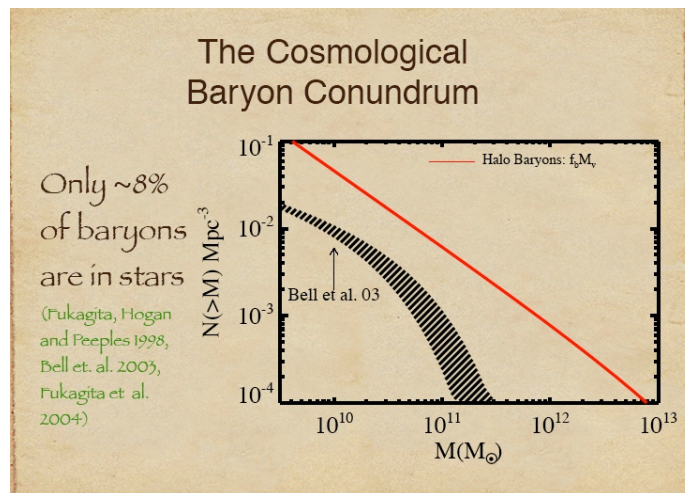
# Formation of structure in the Universe

- Detailed numerical calculations of the formation of structure via the collapse of gravitational perturbations in a  $\Lambda$ CDM universe (Springel et al 2003, White et al 2004) **cannot 'produce' the present day universe without invoking 'feedback' (the injection of energy, heat momentum)**
- Similar results are obtained in analytic work (Ostriker and colleagues)
- The nature of the feedback is not clear, **but must be related to star formation and AGN - the only possible sources with sufficient energy**



# Problems with Structure Formation Models

- Overcooling- standard CDM models with WMAP baryonic fractions give too many baryons in stars (factor of  $>5-10$ )
- Galaxies have the wrong angular momentum distribution
- The timescale of galaxy formation comes out wrong
- The IGM has no metals



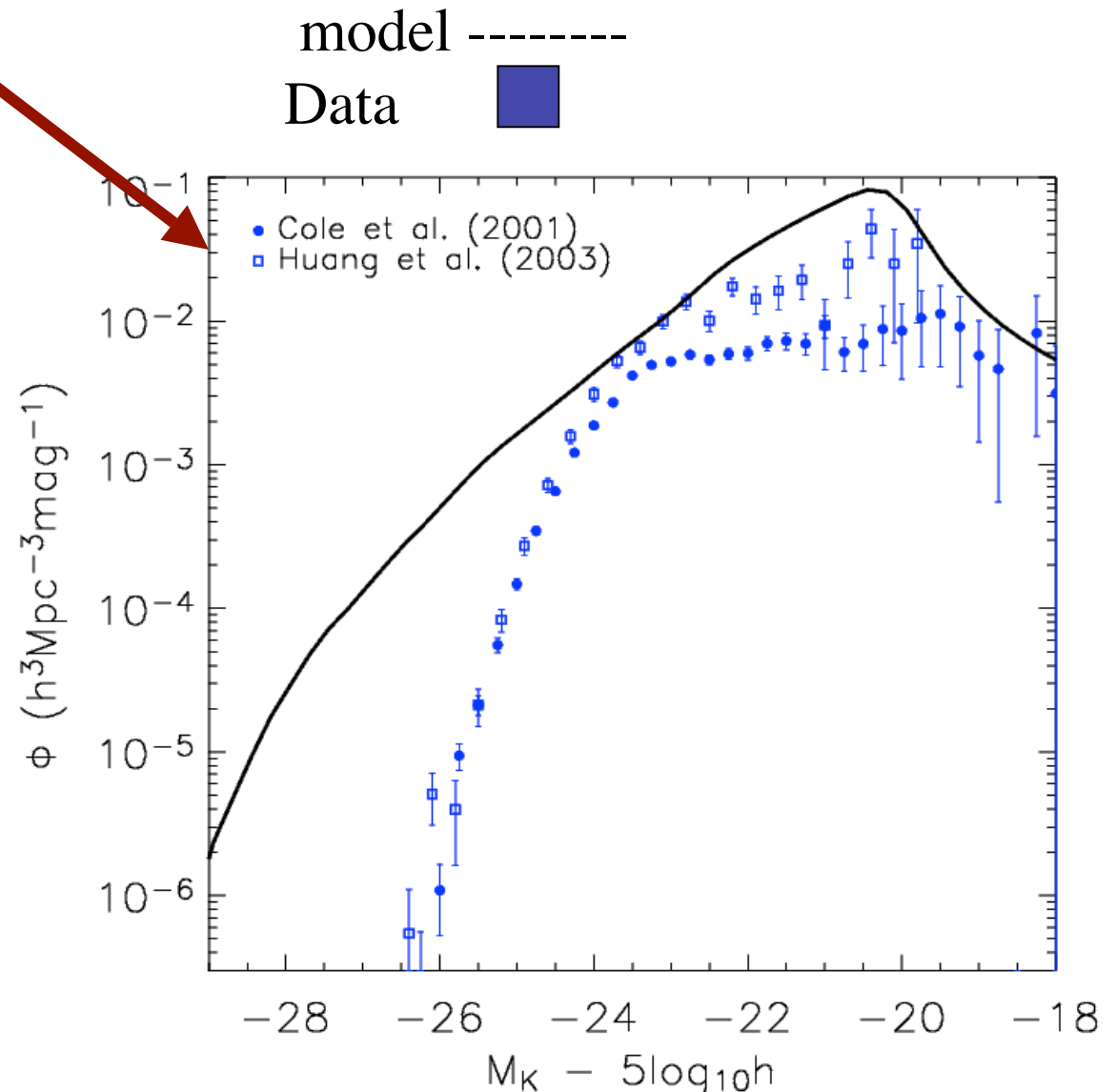
Maller and Bullock 2004

## Science drivers

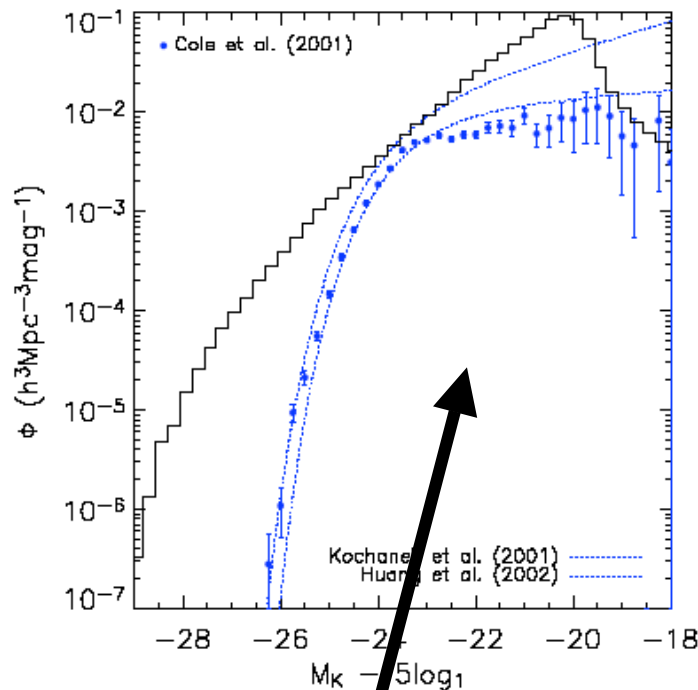
- all structure forms from cooling flows- not understood-fundamental problem
- Structure formation models need “extra physics” is it AGN/radio sources ?
- When where and how structure forms - how to ‘directly’ observe feedback

# Problems with ‘pure’ LCDM

- The Luminosity function of galaxies is wrong
- Major problems with cooling flows in clusters
- Entropy ‘problem’ in groups
- All of these problems are ‘fixed’ by the inclusion of ‘feedback’- non-gravitational energy or momentum injected into the gas which delays cooling, changing everything
- If the extra entropy is due to heat it would require more than 1keV per particle and represent a major event in the universe
- The only viable sources of feedback are AGN (winds or jets) and/or SN in starburst galaxies- Con-X can directly measure energy output of these sources

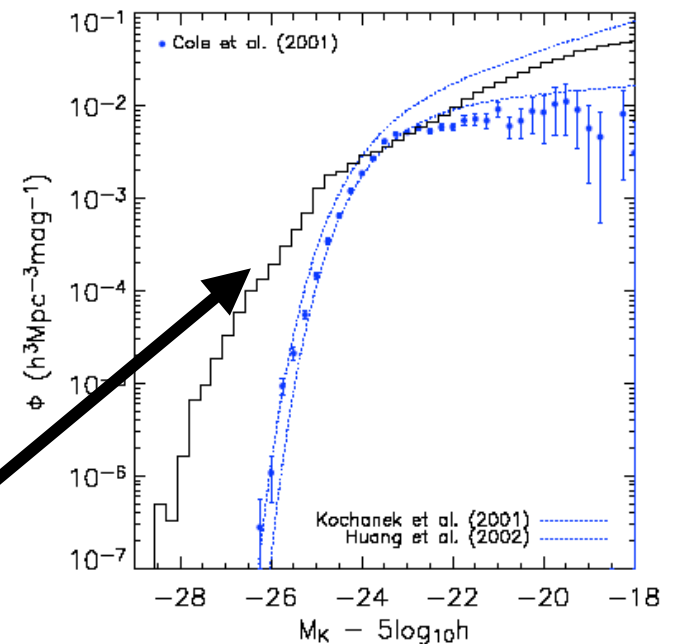


Thanks to S. White, V. Springel, D. Croton



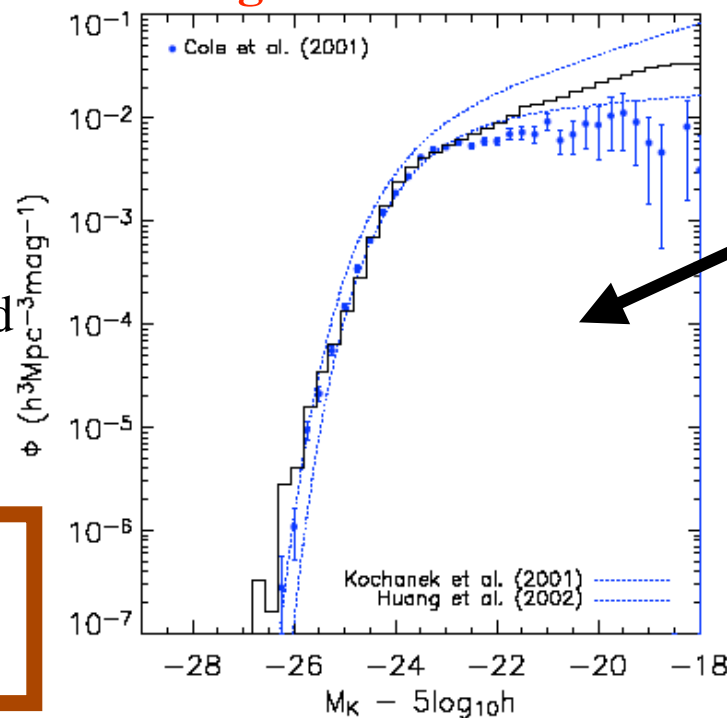
Calculation of K band  
galaxy luminosity  
function in N body  
simulation

Gravity+  
hydrodynamics **no**  
**AGN**+ starburst+  
reionization - **get low**  
**luminosity range**  
**'right'**



Gravity+ hydrodynamics  
only- **get it all wrong**-  
low luminosity, slope,  
high luminosity slope and  
number and mass in  
galaxies

Blue lines are data-  
black models



Gravity+ hydrodynamics  
+AGN+ starburst+  
reionization - **get it all**  
**'right'**

Thanks to V. Springel  
and S. White

# Galaxy formation and accretion on supermassive black holes appear to be closely related

Springel 2004

BLACK HOLES MAY PLAY AN IMPORTANT ROLE IN THEORETICAL GALAXY FORMATION MODELS

Observational evidence suggests a link between BH growth and galaxy formation:

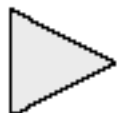
- ▶  $M_B$ - $\sigma$  relation
- ▶ Similarity between cosmic SFR history and quasar evolution

Theoretical models often assume that BH growth is self-regulated by **strong** feedback:

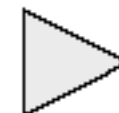
- ▶ Blow out of gas in the halo once a critical  $M_B$  is reached  
Silk & Rees (1998), Wyithe & Loeb (2003)

Feedback by AGN may:

- ▶ Solve the cooling flow riddle in clusters of galaxies
- ▶ Explain the cluster-scaling relations, e.g. the tilt of the  $L_x$ -T relation
- ▶ Explain why ellipticals are so gas-poor
- ▶ Drive metals into the IGM by quasar-driven winds
- ▶ Help to reionize the universe and suppress star formation in small galaxies



***Galaxy formation models need to include the growth and feedback of black holes !***

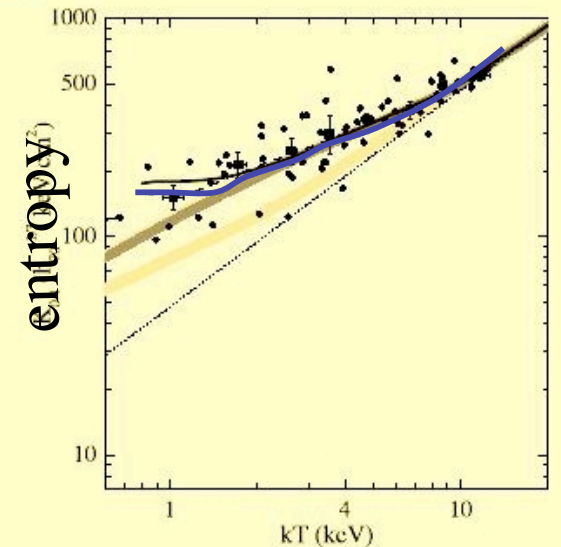
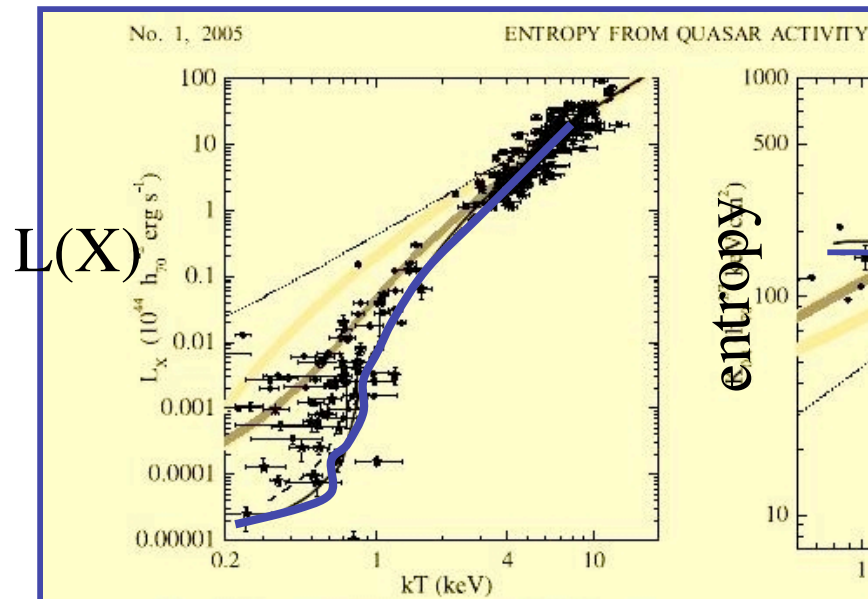
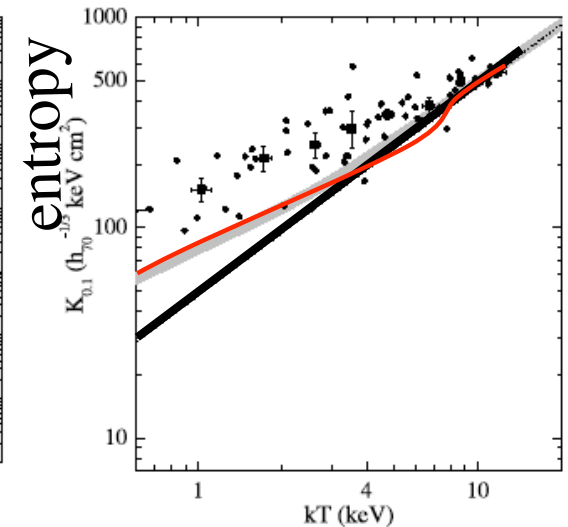
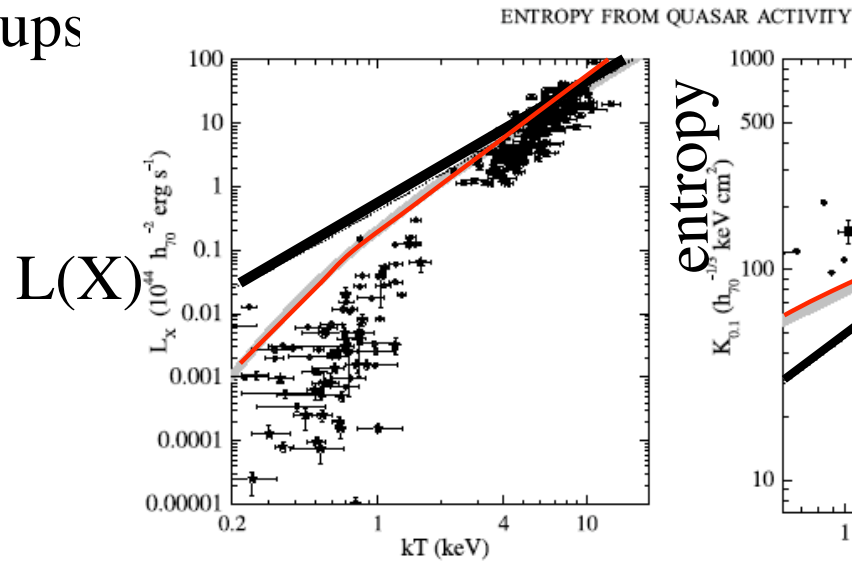


***This also applies to simulations !***

# AGN Heating and Groups

- the x-ray luminosity and entropy profiles (Lapi et al, Dave et al, Borgani et al) **cannot be produced by pure gravitational effects**
- the effects of star formation and cooling **are not sufficient to produce the observed entropy profiles**
- AGN heating (both internal and pre-heating) of same order to solve the galaxy formation problem 'works' to solve entropy problem - **may not solve cooling flow problem**

- just hydro
- star formation
- AGN +SFR



Direct simulations of star formation in cosmological volumes are very difficult

## COMMON HEADACHES OF SIMULATORS OF GALAXY FORMATION

- Cooling catastrophe & overproduction of stars
- Thermal supernova-feedback fails to regulate star formation, and fails to explain metal enrichment of the IGM
- Collapse of gas halted by numerical resolution not by physics

*DATA ARE CRUCIAL*

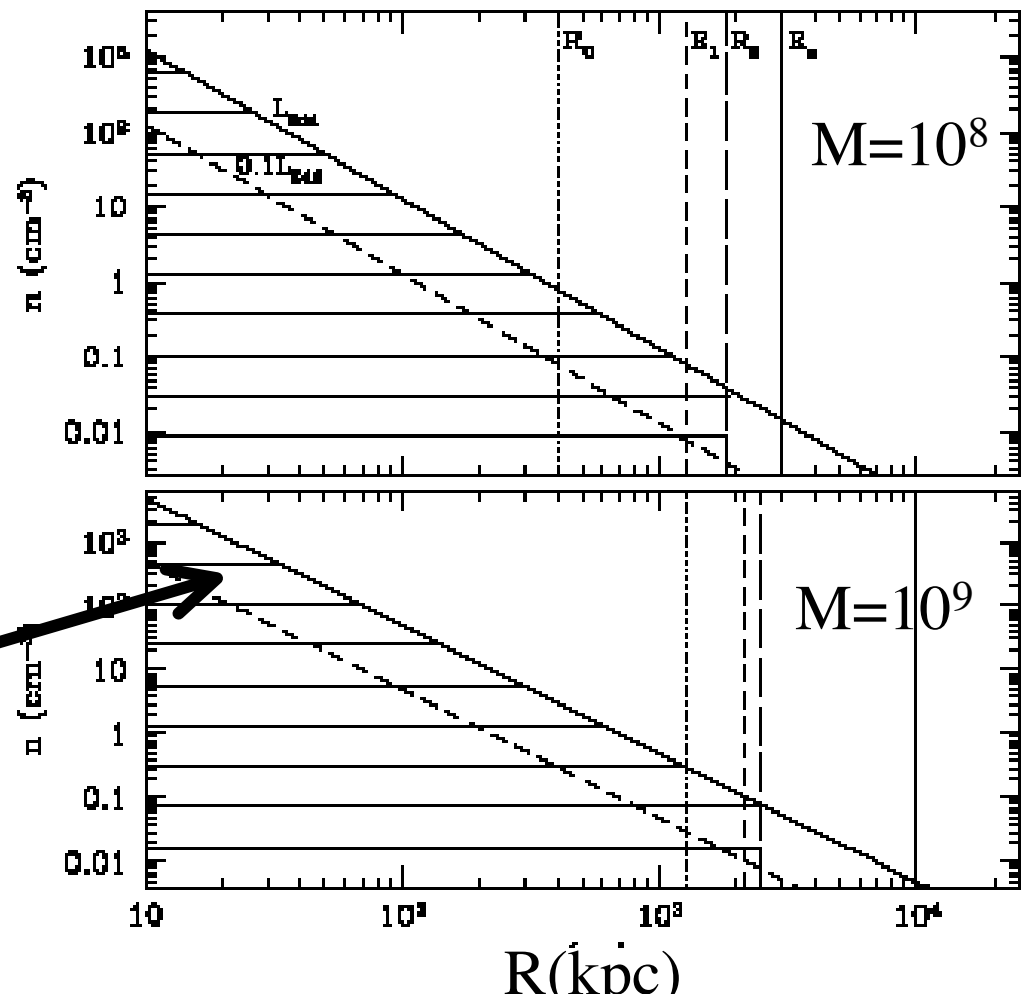
# How Do the AGN Influence their environment?

- Radio jets/double sources
- Mechanical winds
- Radiation
- Each one of these has visible and testable effects

- radiation effects have to occur (Sazonov et al 2004) and can photo-ionize and Compton heat the gas in the host galaxy to  $kT \sim 2 \times 10^7 \text{ K}$  - almost exactly what is needed for the 'entropy' problem.
- However the gas is only heated at  $R < 0.5\text{-}10 \text{ kpc}$  and thus can strongly effect spheroid evolution but not groups or clusters.

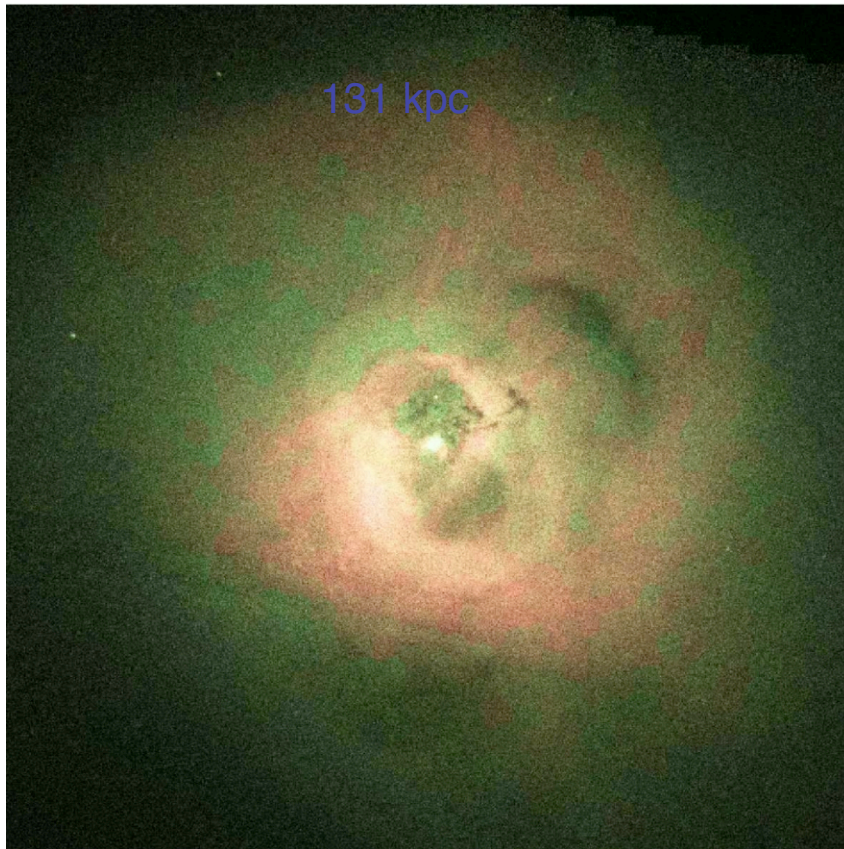
$$R_C = \left( \frac{\sigma_T \epsilon M_{\text{BH}}}{3\pi m_e} \right)^{1/2} = 400 \text{ pc} \left( \frac{\epsilon}{0.1} \right)^{1/2} \left( \frac{M_{\text{BH}}}{10^8 M_\odot} \right)^{1/2}. \quad (5)$$

this radius, a low density, fully photoionized gas will be heated to the Compton temperature  $T_C \approx 2 \text{ keV}$  characteristic of the quasar spectral output.  
RADIATIVE FEEDBACK FROM  $\nu_{\text{UV}}$

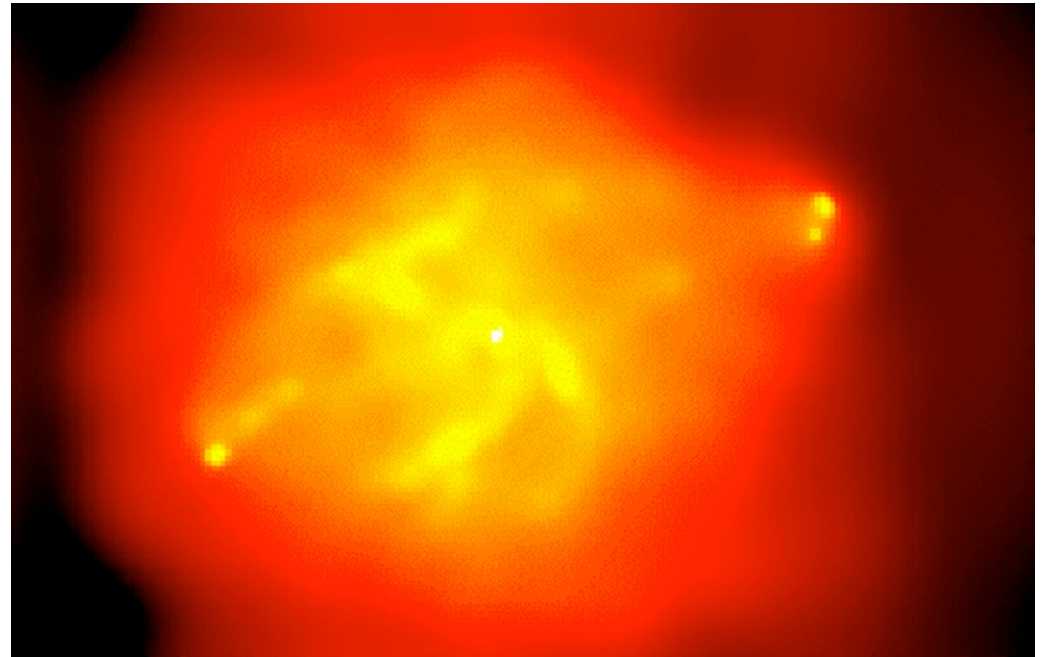


# Direct Evidence From Chandra Images of Influence of Black holes on their Environment

## X-ray temperature Map of Perseus cluster- AGN at the center



Fabian et al. 2003



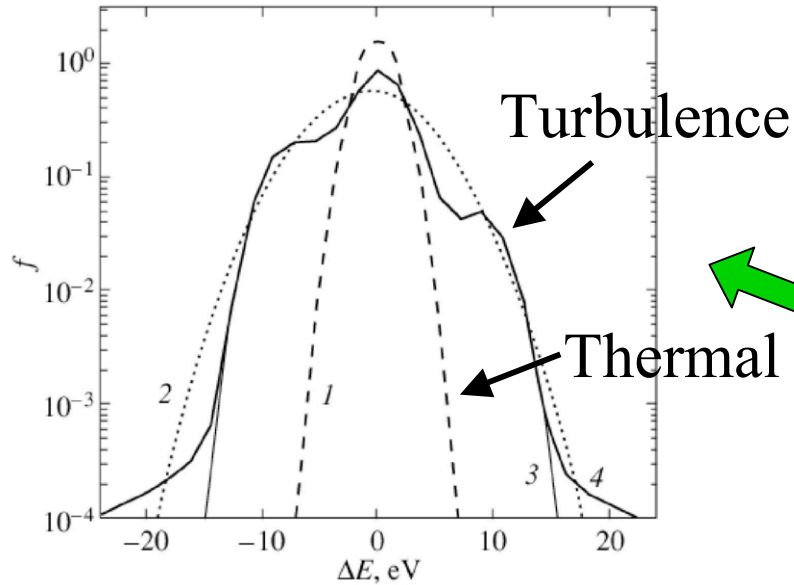
- Chandra x-ray image of Cygnus-A Cluster of Galaxies with AGN in center (Wilson et al 2002)- notice the structure related to the radio source

## What can we learn about energy deposition in groups clusters

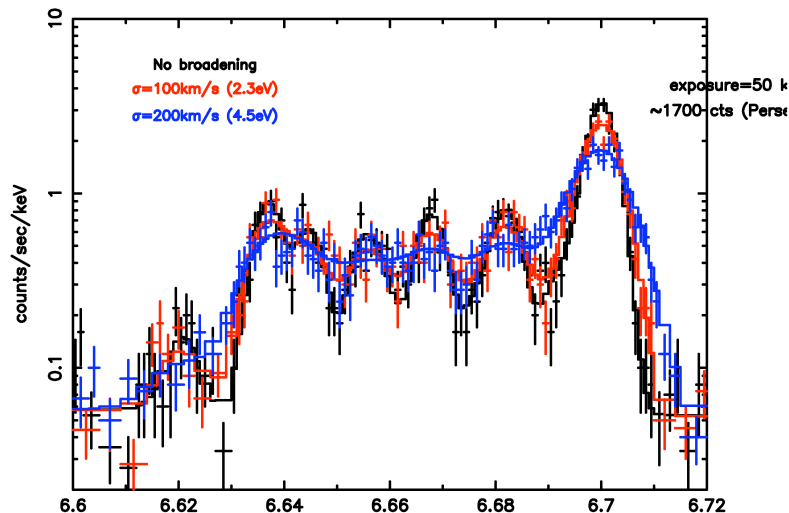
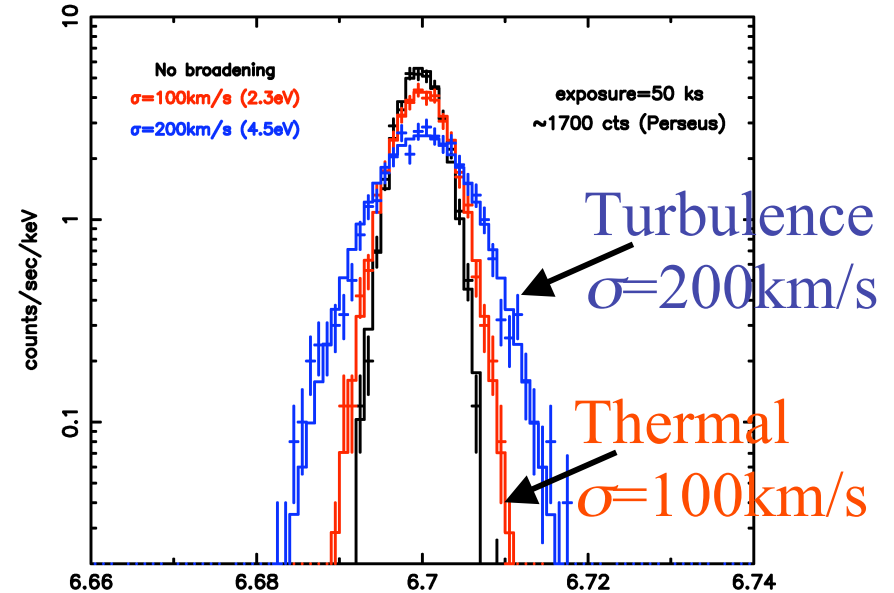
- Turbulence/velocity shear from line shapes
- transport properties/dissipation
- Precise abundances
- Radiative energy of nucleus
- magnetic field from IC scattering ( hard emission)
- Thermal state of the gas
- Optical depth of gas (resonance scattering) allows details of velocity

# Line profile from a turbulent gas

Inovamov and Sunyaev 03



Simulated XRS Fe line profile  
1700 photons  $\Leftrightarrow$  Perseus: 50 ksec



APEC 3 keV (1700 photons)

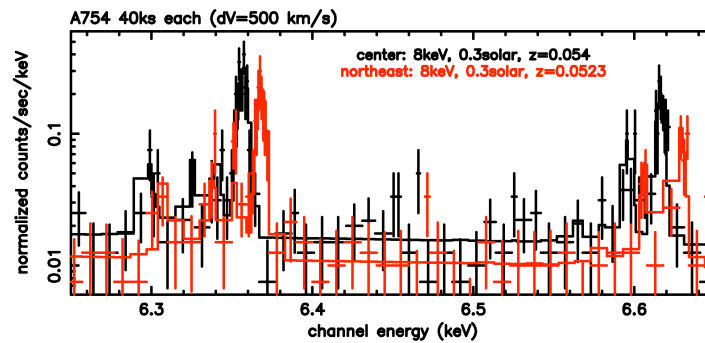
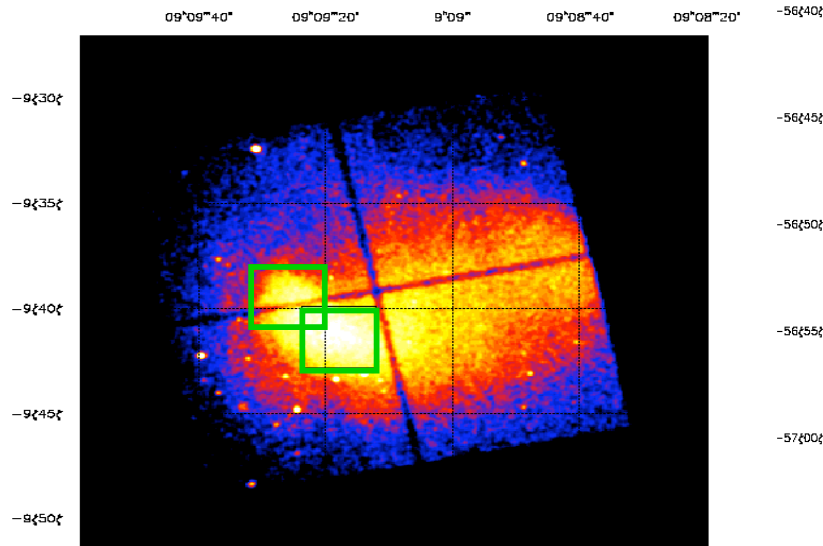
$\sigma = 100$  km/s (2.3 eV)

$\sigma = 200$  km/s (4.5 eV)

Accuracy of line width:  $\pm 0.3$  eV

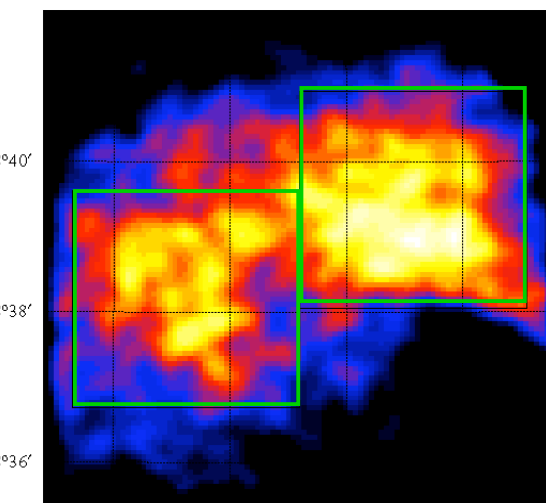
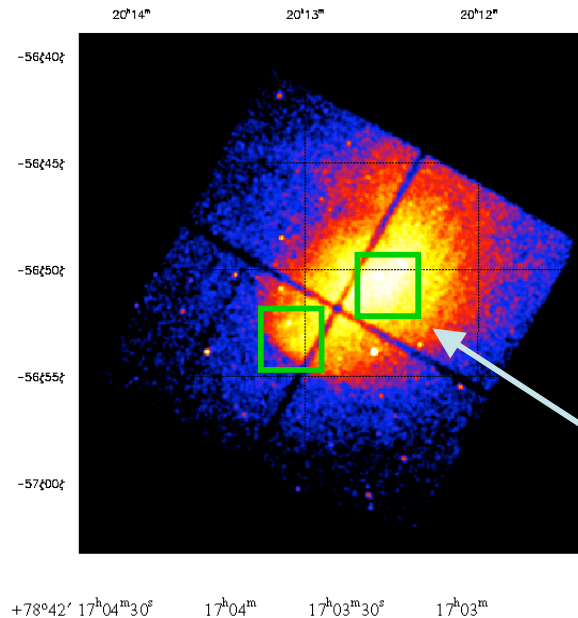
# Cluster Velocity Field with AstroE2

A754 ( $z = 0.054$ )



40 ksec x 2

$\Delta v = 500$  km/s

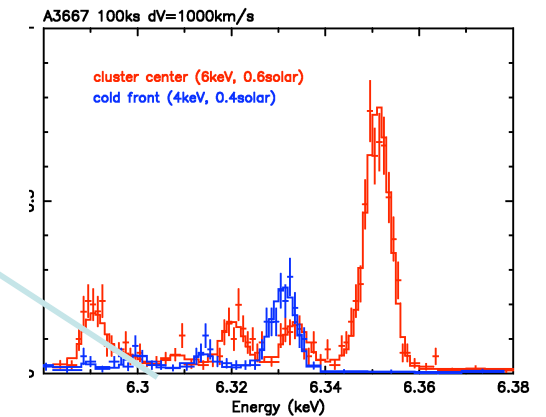


1000 km/s

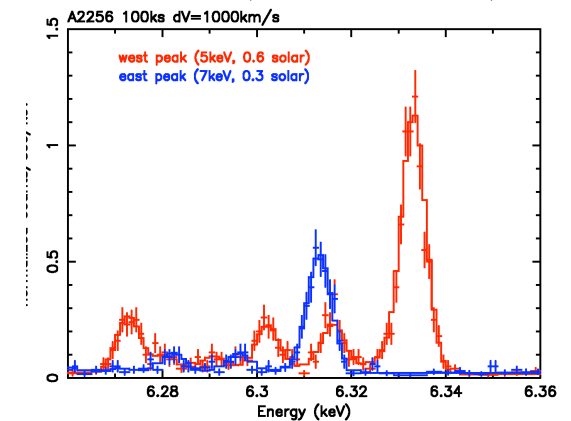
XRS

1000 km/s

A3667 ( $z = 0.055$ )



100 ksec x 2  
A2256 ( $z = 0.058$ )



## How do AGN influence their environment?

- How do the AGN interact with the gas
- What is the source of the energy (jets, AGN winds, sound waves) that is influencing the gas
- **If jets are the source, how does this actually work? - No direct sign of heating in clusters where jet/gas interaction is observed**

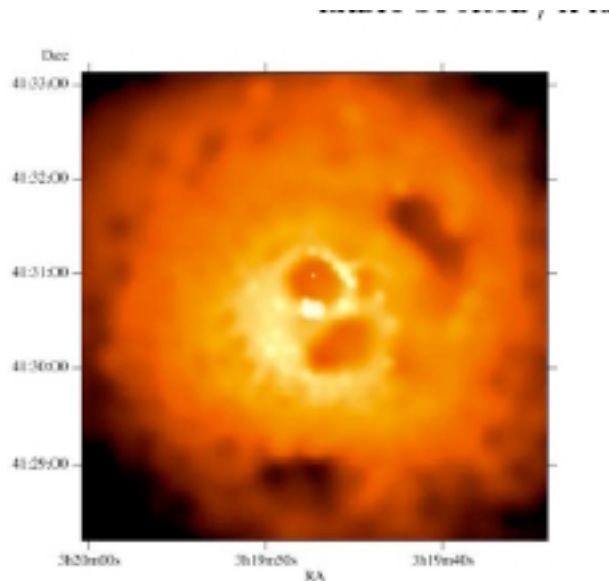


FIG. 11.— Adaptively-smoothed *Chandra* image of the center of the Perseus cluster. The inner bubbles that are associated with the current 1.4 GHz radio emission are seen, as well as two about

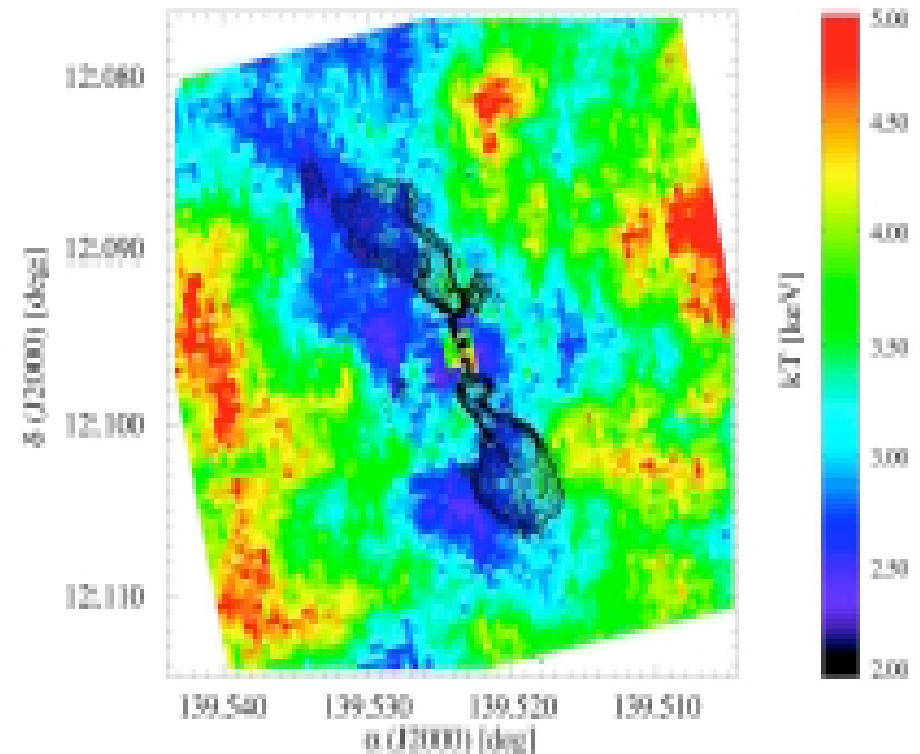
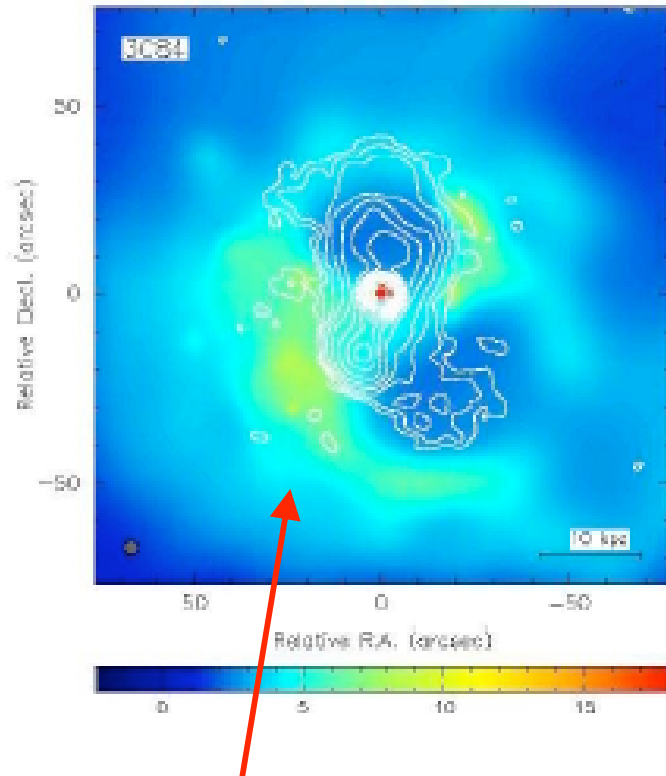


FIG. 2.— The temperature map of the Hydra A cluster, with radio contours superposed (Nuken et al. 2002). The coolest gas is found in the regions surrounding the radio sources, and there is no evidence for current strong-shock heating of the ICM from the radio lobes.

X-ray intensity map of the Perseus cluster- the central holes are where the radio lobes are- the outer holes are “ghost cavities” (Fabian et al 2002)

# What are the possible sources of heat?- Heating by AGN ?



Chandra image of the interaction of the radio source and x-ray gas in the Perseus cluster (Fabian et al 2002)

- The interaction between the radio sources and cluster gas has been imaged in many clusters by Chandra

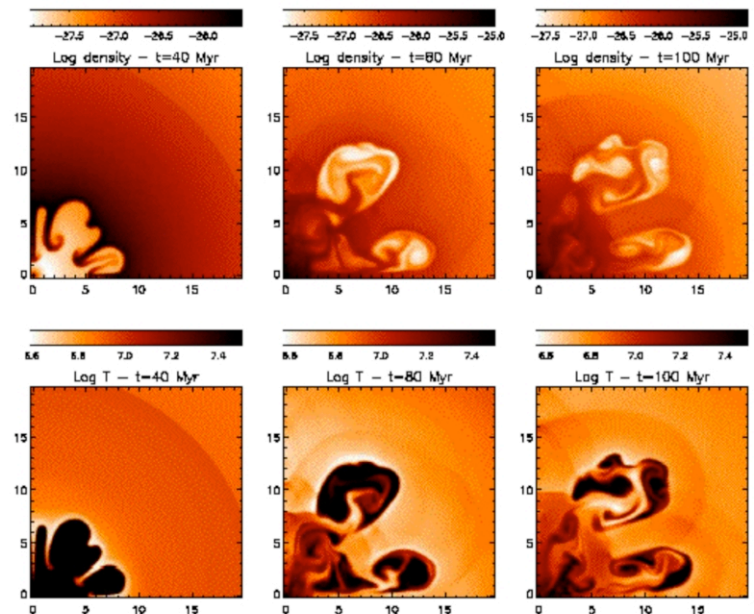
There is no direct evidence of heating- the radio plasma seems to “push” the x-ray gas aside.

*However theoretical work by several authors indicates that heating is happening.*

calculation of heating in a cluster

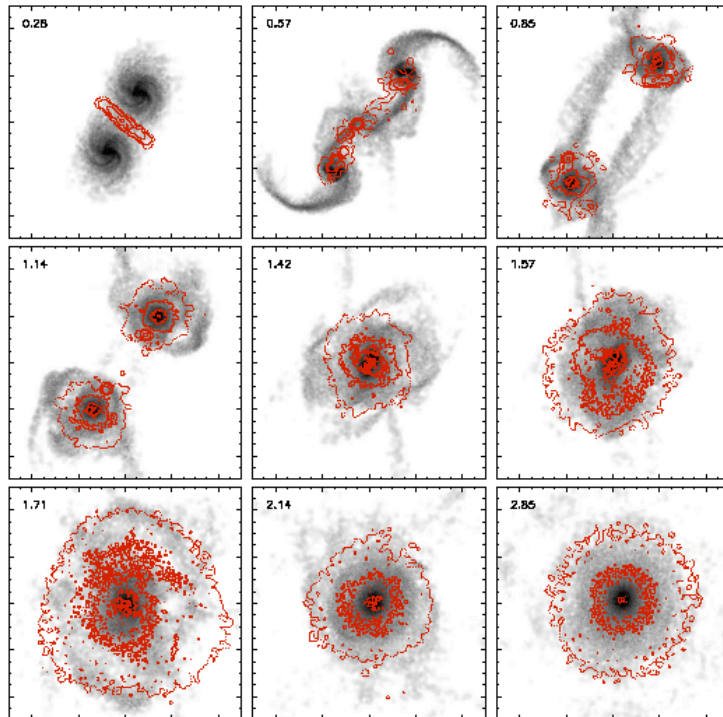
Top panel is density

Bottom is temperature  
(Brighenti and Mathews 2002)

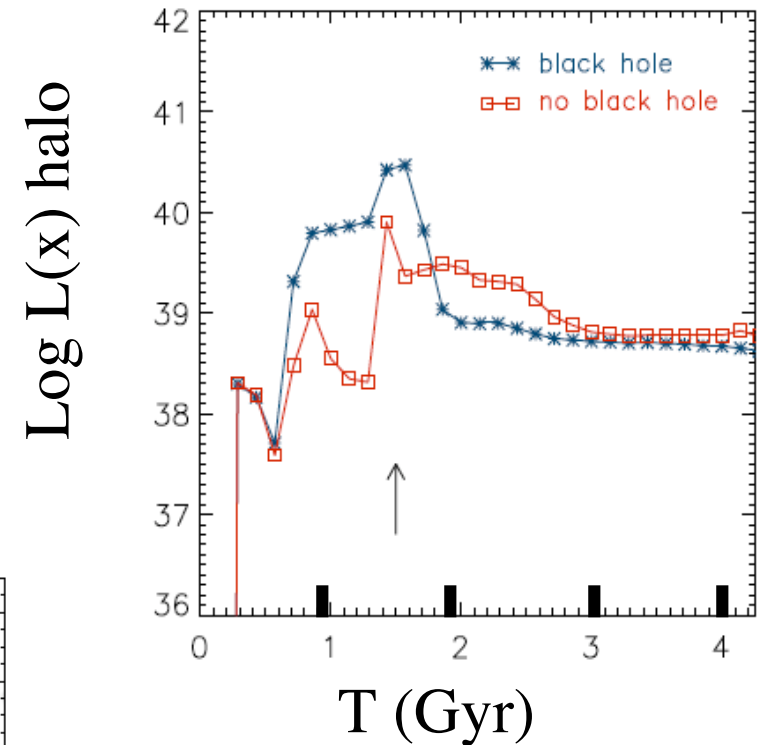
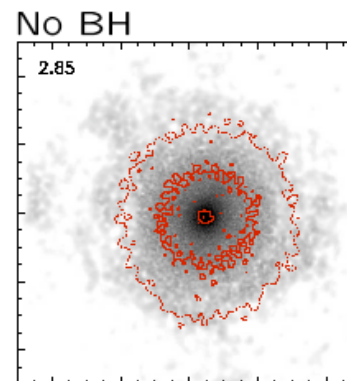
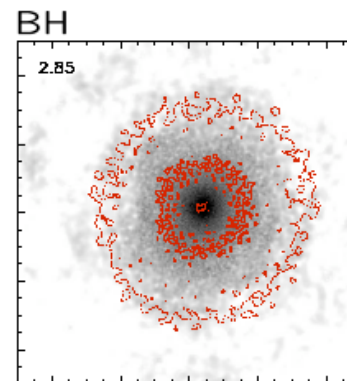


# Simulations of Black holes on Environment

- Merging galaxies- (Di Matteo et al 2005, thanks to TJ Cox)



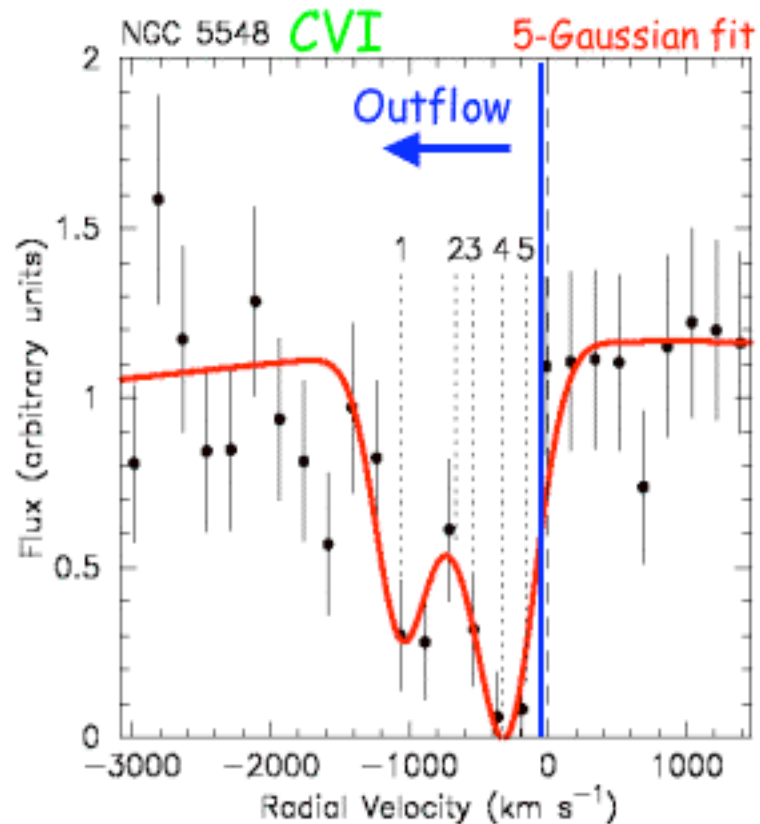
X-ray emission in red



In merger of two galaxies with and without a central black hole

- the overall temperature and morphology of the x-ray halos do not change-
- but the luminosity changes by  $\sim 2-10$

## Winds In AGN- A Possible source of heating



CXO/LETGS **Courtesy Ian George**

Outflow "always" seen in Seyferts

~ 0 to ~1500 km/s

No significant infall (yet)

NGC4051 (Collinge et al 2001)

Mrk509 (Yaqoob et al 2003)

MCG-6 (Lee et al 2001)

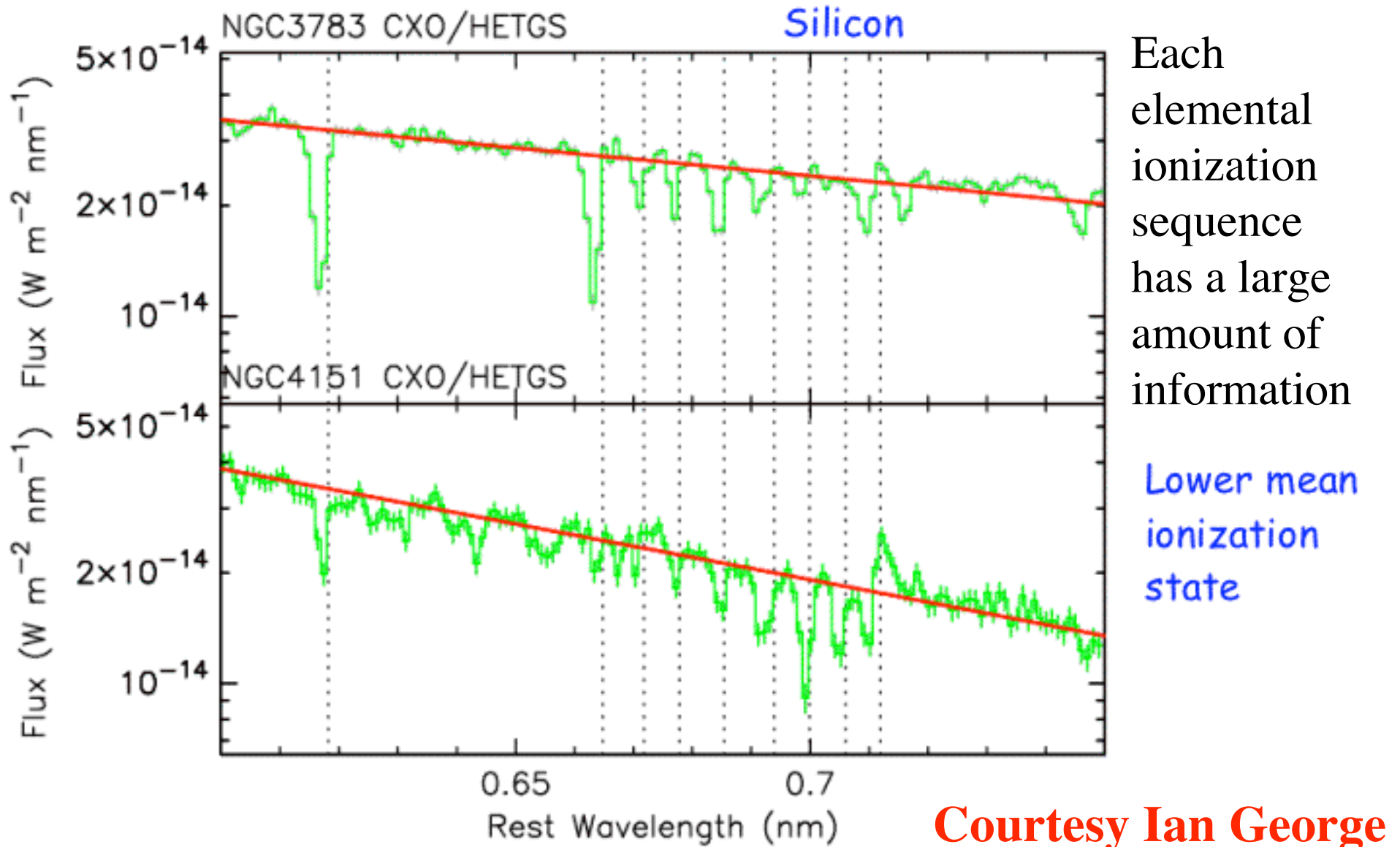
....etc etc

(Crenshaw et al 2003)

(adapted from Kaastra et al 2002)

Thanks to M. Cappi for detailed discussion yesterday

Much of the physics of AGN winds can be done with Si and S  
Wide range in ionization 1.8-2.7 keV



# Mass-Flow Estimates

We see mass outflow

believe/sure photoionized  $\Rightarrow$  radius  $\leq$  few pc

$r_{\text{start}}$	mass supply	implications ( $C_f = 0.5$ )
small ( $\ll 1\text{pc}$ )	accretion disk Interesting!!	$\dot{m}_{\text{out}} \leq \dot{m}_{\text{acc}}$ $t_{\text{equil}} \sim \text{instant}$
...	... <i>progresively less interesting</i>	
...	... <i>wrt b.h./inner disk</i>	
...	... <i>physics (?)</i>	
large ( $\sim 1\text{pc}$ )	"torus"/outer disk	Interesting!! $\dot{m}_{\text{out}} \sim \text{few} \times 10^2 \dot{m}_{\text{acc}}!$ $t_{\text{equil}} \sim \text{days}$

If true- winds carry a lot of energy- 1/2 of low z AGN have them

## Winds In AGN

- In  $>1/2$  of all high S/N Chandra/XMM observations of AGN one detects outflowing winds
- In deep fields  $\sim 15\%$  of luminous galaxies are x-ray sources (high duty cycle)
- $V \sim 500\text{--}2000\text{ km/sec}$
- Mass and energy flux in wind is rather uncertain (Chelouche 2005) but may reach  $L_{\text{wind}} \sim 0.1 L_{\text{radiation}}$
- Maybe more mass at higher ionization states
- *This maybe the mechanism by which AGN 'heat' the universe*
- Need to obtain *time resolved, high resolution spectra* for **a large number of objects** to get accurate estimates of mass and energy flux in wind and dependence on AGN parameters

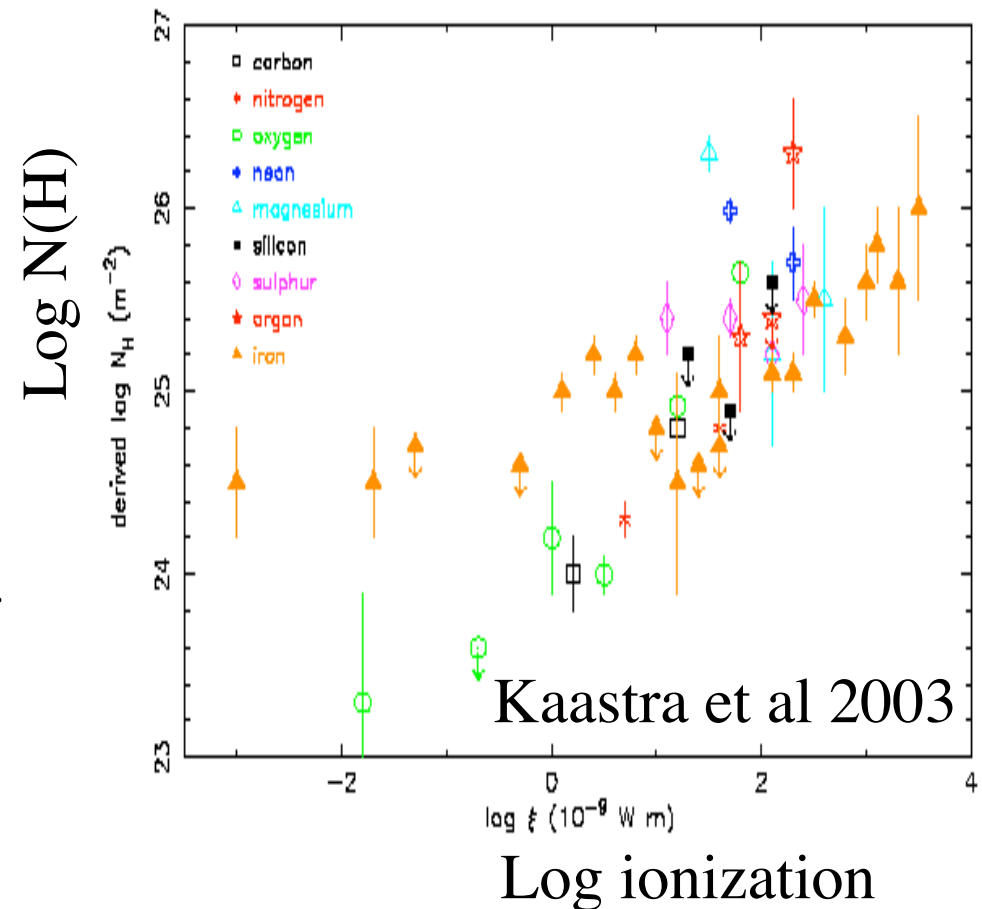
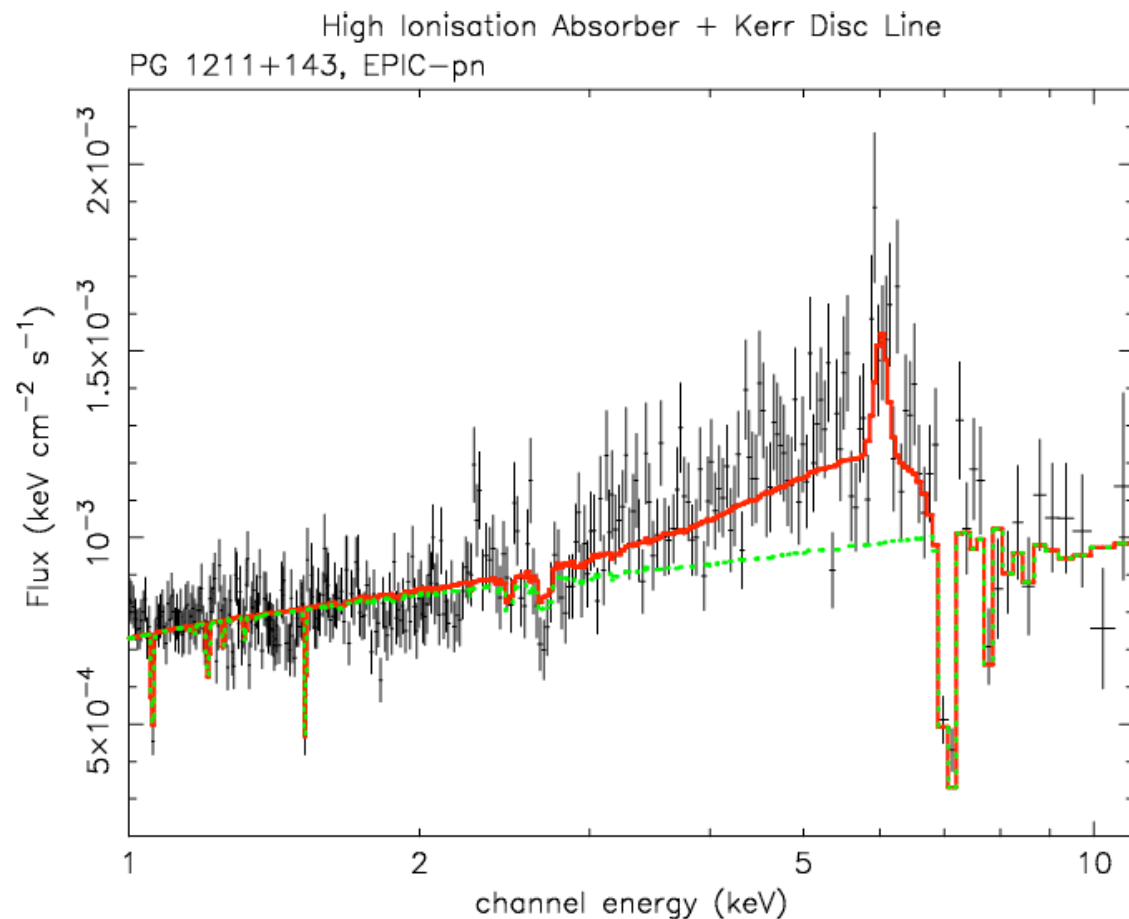


Figure 5. The derived absorbing column density per ion as derived from the measured column density for the RGS observation. There is an increase of the derived column density with higher ionization.

To derive mass/energy flux need to derive gas density- multi-epoch observations  
Only possible if observations short

## Very High Velocity Outflows

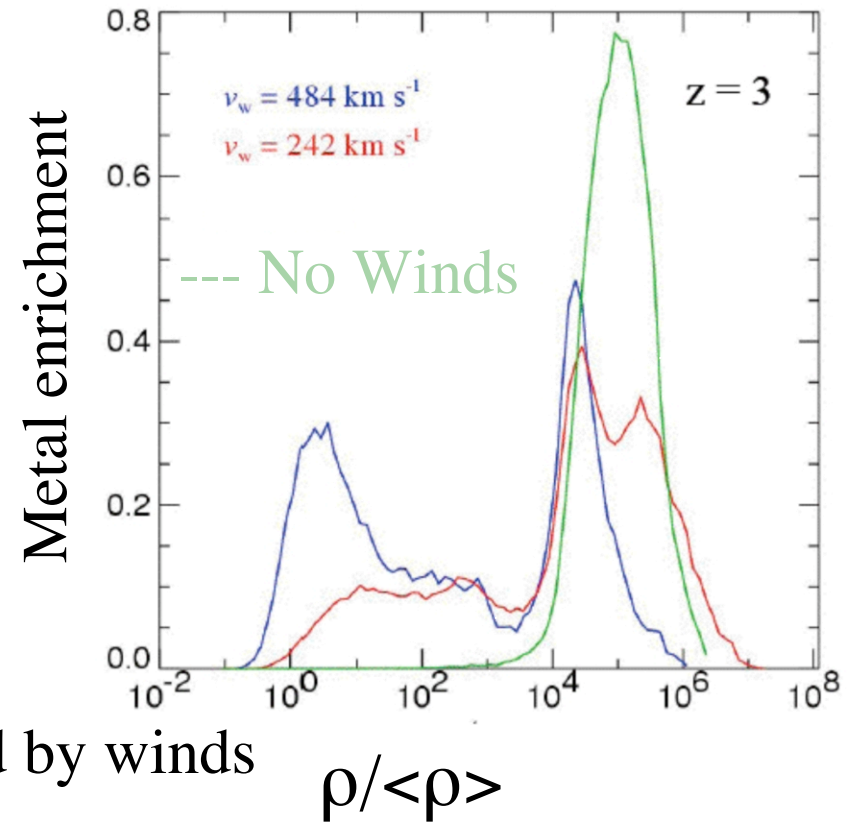
- In several objects outflow velocities of  $\sim 0.1c$  are detected (Hasinger et al 2003, Pounds et al 2002, Reeves et al 2003) implying very high energy and mass loss rates.
- These high velocities are only seen in the Fe K lines
- Its possible that such features are common but hard to see in CCD spectra



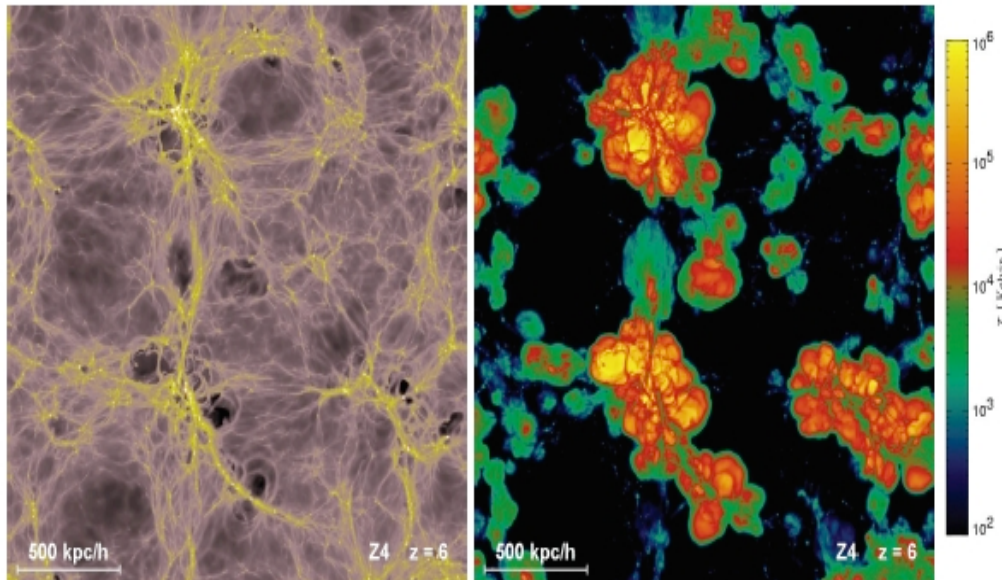
PG1211- blue shifted resonance Fe absorption feature  $V \sim 0.08c$  (Reeves et al 2003)

## Effect on IGM

- The only way that metals get into the IGM is via winds
- Direct observations of metals at  $z > 3$  in IGM (Songalia et al 2004) and winds in star forming galaxies (Steidel et al 2005) show that this process is happening
- Steidel finds wind velocities of  $\sim 500$  km/sec are 'ubiquitous' in star forming  $z \sim 3$  galaxies
- Are the winds driven solely by star formation or are AGN also important?



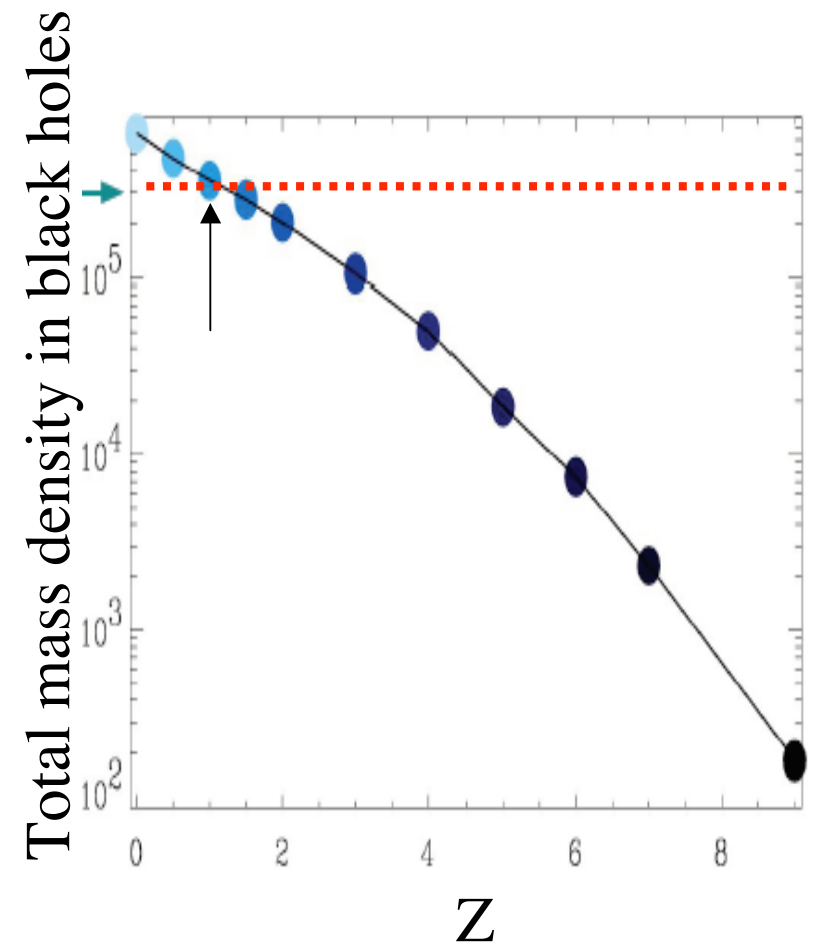
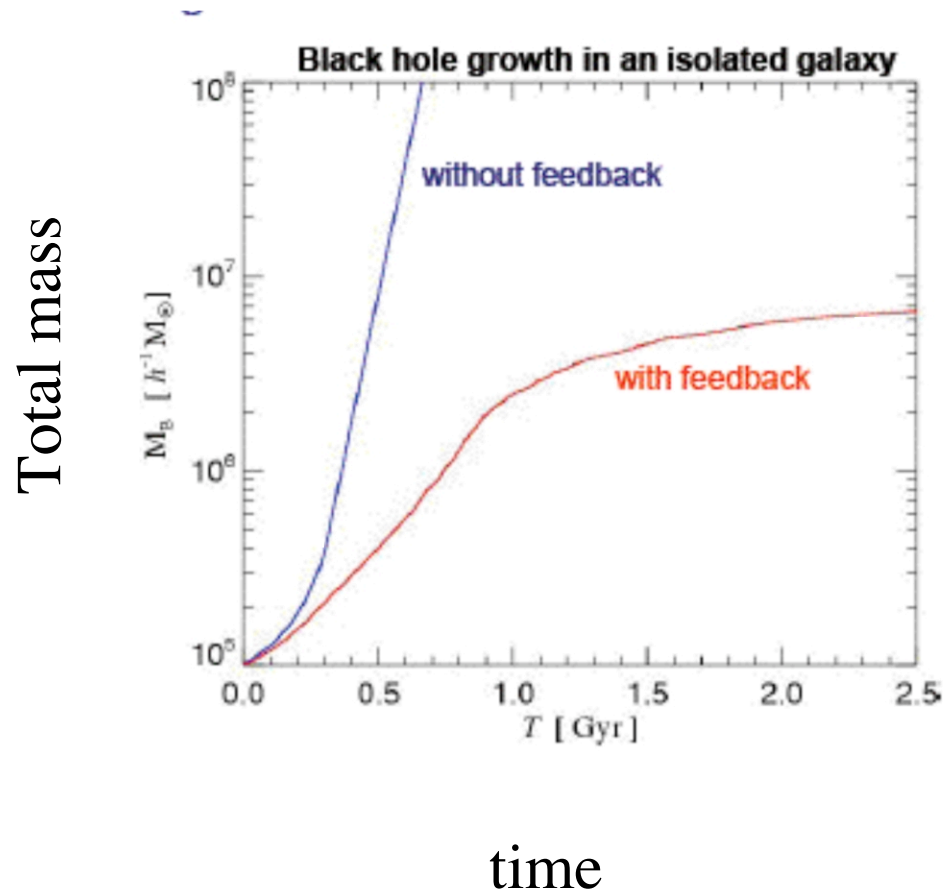
Hot metal rich bubbles in IGM produced by winds



Metallicity in IGM with  
Low, medium speed winds  
and no winds

## Growth of Black holes in feedback scenario

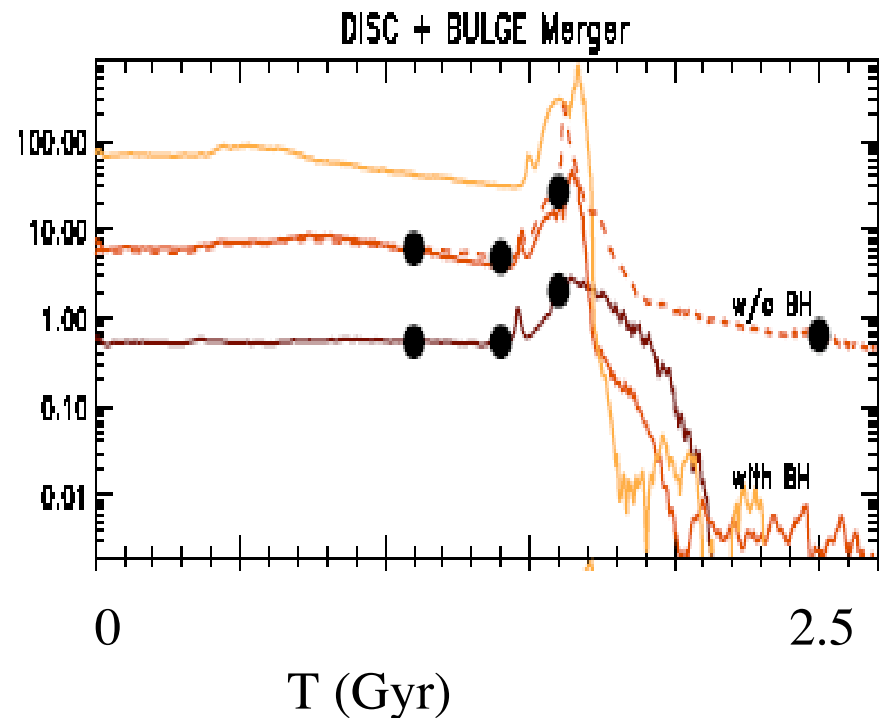
- Black holes show  $\sim 1/2$  their mass growth at  $z < 1.5$  in the Springel et al simulations with feedback
- With no feedback growth is biased towards earlier epochs



# AGN Effect ON SFR

- Di Matteo et al show that there is a major effect of the BH on the star formation rate during a merger.
- Truncation of the SFR rate due to AGN feedback makes the galaxy color ‘redden’ faster- in better agreement with recent data.

SFR



The big question is how to observe

When, where and how the energy is produced and deposited.

AGN winds/jets

Starburst winds

What is required is dynamics and mass flux- only visible with x-ray spectroscopy

# The properties of merger remnants are altered by the AGN activity

## THE FATE OF THE GAS IN A MERGER WITH AND WITHOUT BLACK HOLES

### Springel et al 2004

#### Merger without black hole:

initial gas mass:  $1.56 \times 10^{10} h^{-1} M_{\odot}$

- 89.0% turned into stars
- 0.05% expelled from halo
- 1.2% cold, star forming gas
- 9.8% diffuse gas in halo

#### X-ray luminosity

$\sim 9.5 \times 10^{39} \text{ erg s}^{-1}$

#### Residual star formation rate

$\sim 0.13 M_{\odot} \text{ yr}^{-1}$

(1 Gyr after galaxy coalescence)

#### Merger with black hole:

initial gas mass:  $1.56 \times 10^{10} h^{-1} M_{\odot}$



- 51.9% turned into stars
- 35.3% expelled from halo
- 0% cold, star forming gas
- 11.1% diffuse gas in halo
- 1.6% swallowed by BH(s)

#### X-ray luminosity

$\sim 4.8 \times 10^{38} \text{ erg s}^{-1}$

#### Residual star formation rate

$0 M_{\odot} \text{ yr}^{-1}$

(1 Gyr after galaxy coalescence)

Galaxy formation and accretion on supermassive black holes appear to be closely related

BLACK HOLES MAY PLAY AN IMPORTANT ROLE IN THEORETICAL GALAXY FORMATION MODELS

Observational evidence suggests a link between BH growth and galaxy formation:

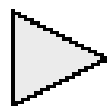
- ▶  $M_B$ - $\sigma$  relation
- ▶ Similarity between cosmic SFR history and quasar evolution

Theoretical models often assume that BH growth is self-regulated by **strong** feedback:

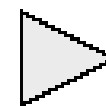
- ▶ Blow out of gas in the halo once a critical  $M_B$  is reached  
Silk & Rees (1998), Wyithe & Loeb (2003)

Feedback by AGN may:

- ▶ Solve the cooling flow riddle in clusters of galaxies
- ▶ Explain the cluster-scaling relations, e.g. the tilt of the  $L_x$ -T relation
- ▶ Explain why ellipticals are so gas-poor
- ▶ Drive metals into the IGM by quasar-driven winds
- ▶ Help to reionize the universe and suppress star formation in small galaxies



*Galaxy formation models need to include the growth and feedback of black holes !*



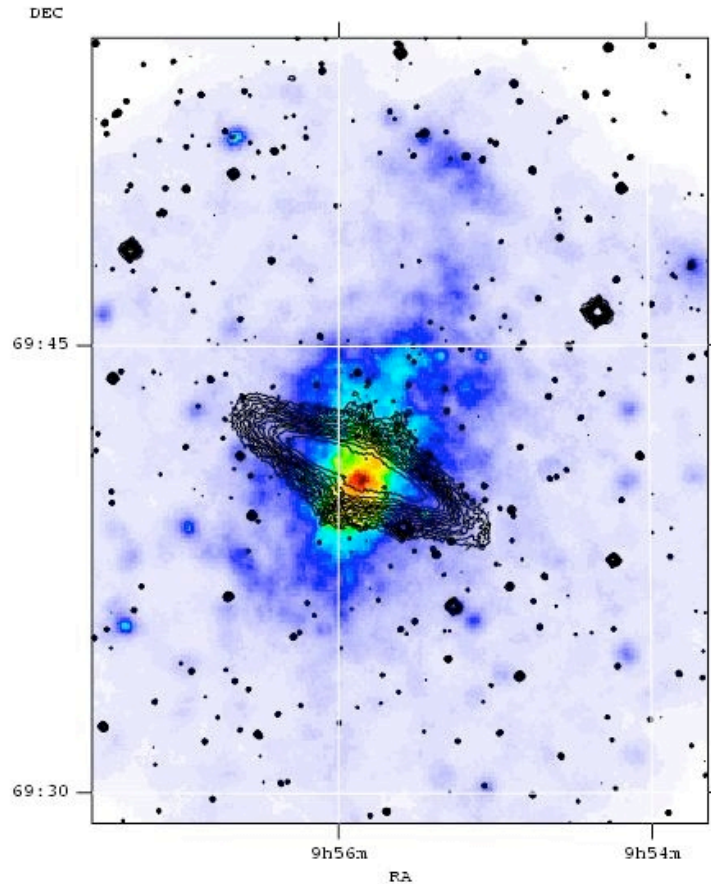
*This also applies to simulations !*

What are the other possible sources of heat?-  
Rapid star formation drives galactic winds

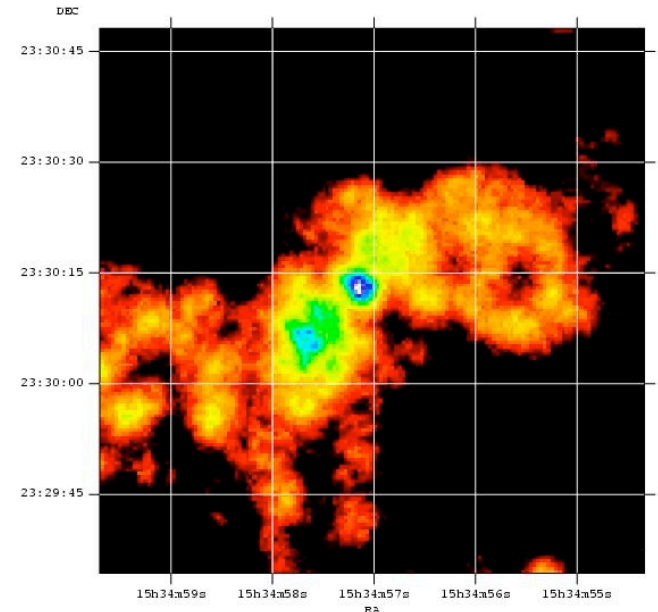
**The galactic wind in M82 with XMM-**  
the x-ray image is in color, the galaxy in black.

The wind is observed out  $\sim 10$  kpc from the plane of the galaxy. The XMM spectra show metals lines at the largest scales -  
**this should be directly observable as velocities in the metal lines**

M82- Galaxy in Black XMM X-ray Image in Color



Chandra Soft X-ray Image of Arp 220



Chandra image of the galactic wind in Arp 220  
 $\sim 15$  kpc in size

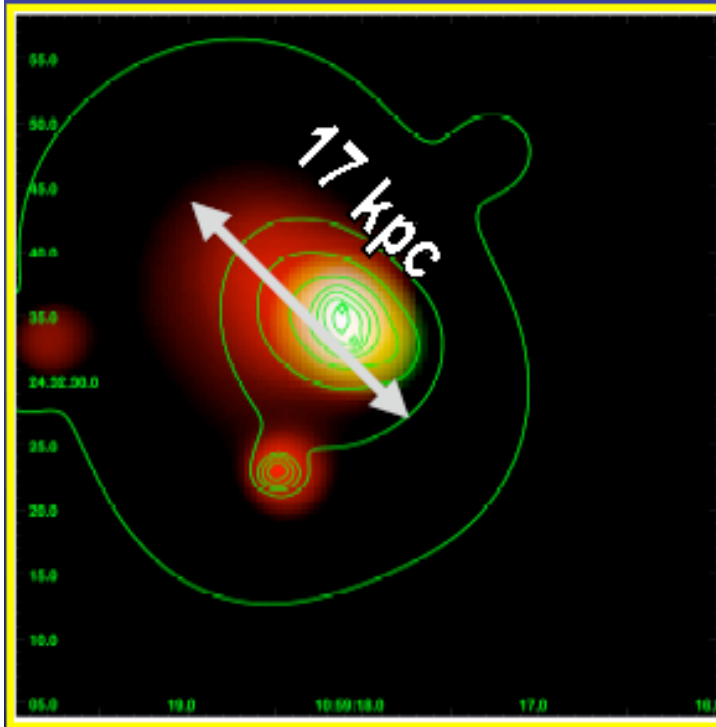
# ULIRGS Have superwinds

C. Martin

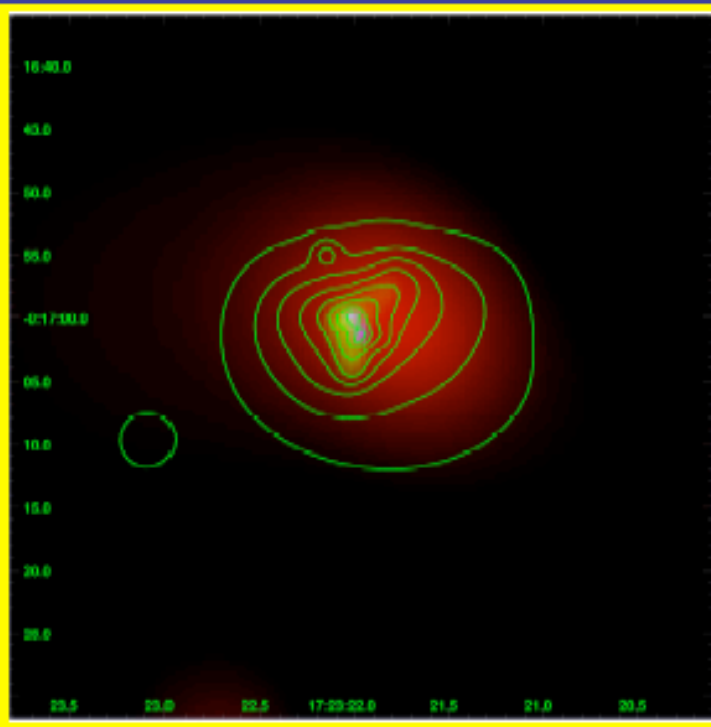
- Deep Chandra Images show that ULIRGS have superwinds  $\sim 10\text{kpc}$  in size - set by surface brightness limit of Chandra
- At  $z=1$  plate scale is  $8\text{kpc/arc sec}$  so  $20\text{kpc}$  will be hard  $1''=4.4\text{kpc}$ ,  $z=0.3$

## Do ULIGs Have Hot Winds?

IRAS10565+2448



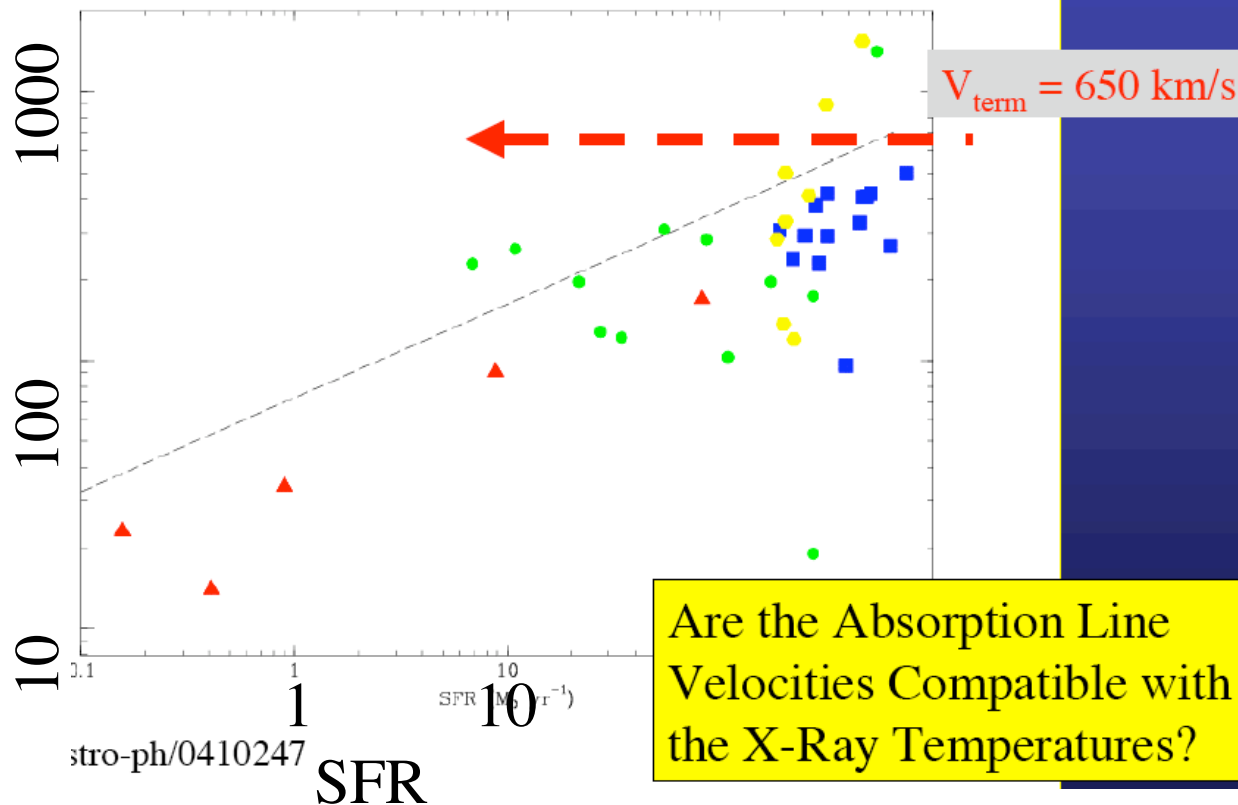
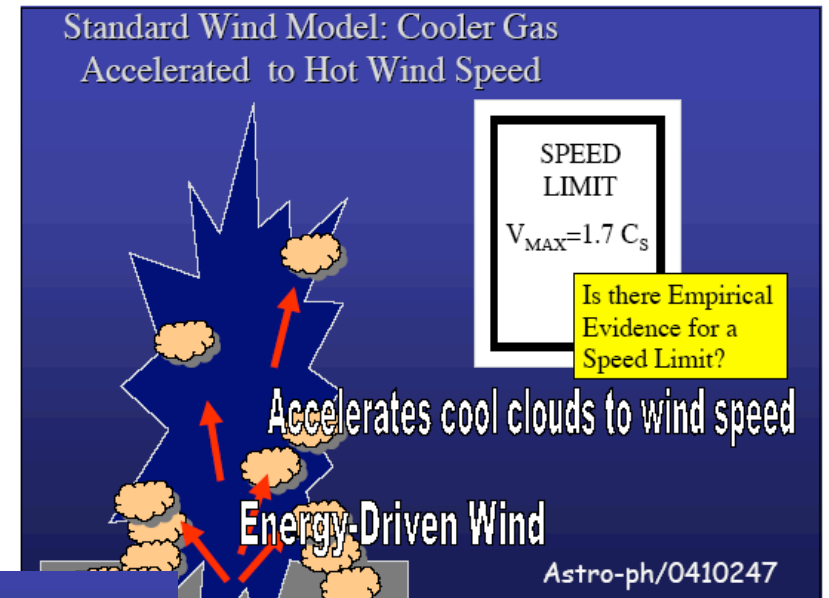
IRAS17208-0014



Images by Victor Sciortino (UCSB Physics)

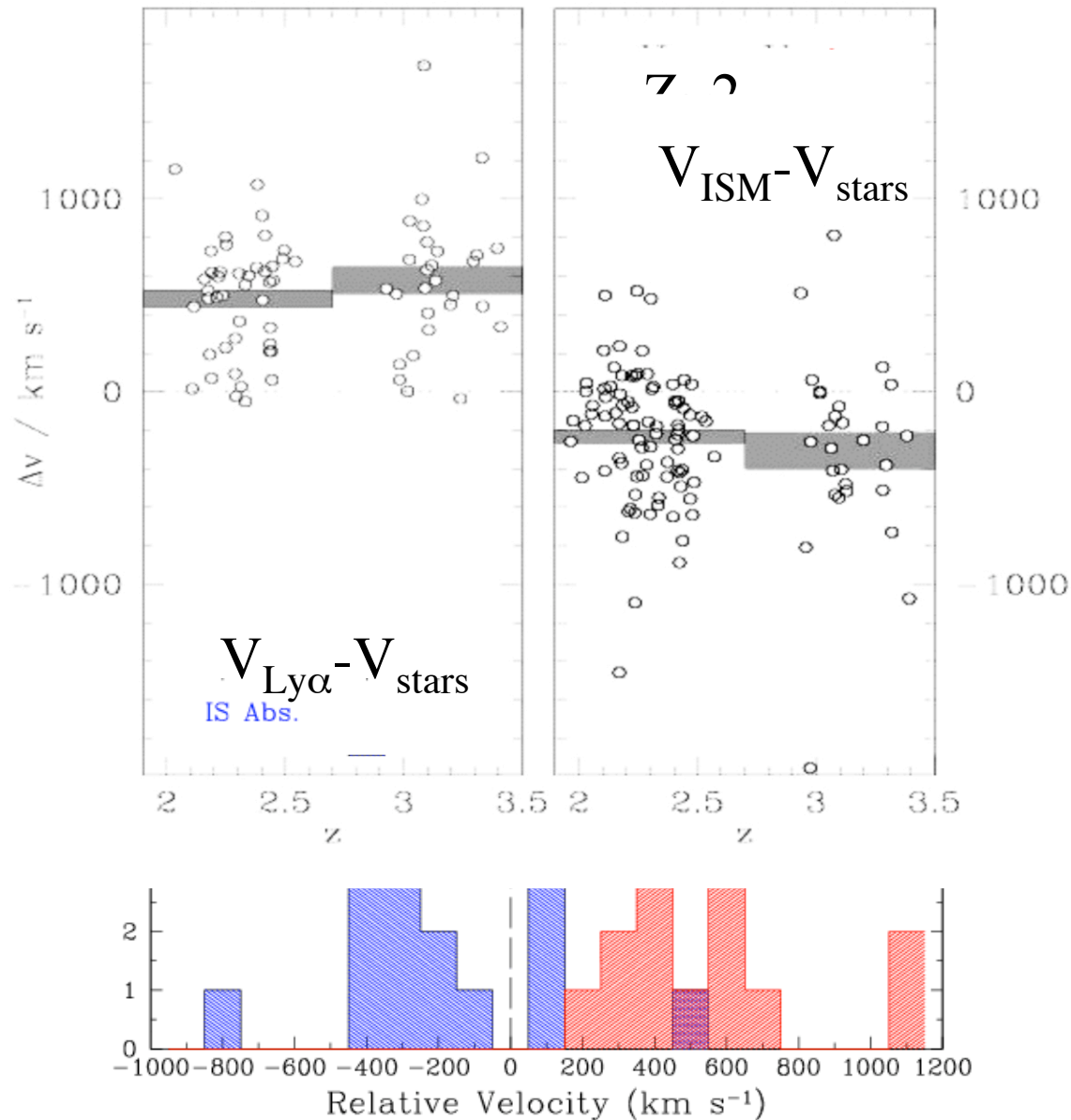
# Starburst Winds at low redshift

- At low  $z$  (Martin et al , Heckman et al) optical absorption line spectroscopy gives wind speeds of 50-650 km/sec
- Easily seen with calorimeters



# Galactic Scale Winds: Still Going Strong at $z \sim 2$ (Steidel 2005)

Velocity Offsets in BX/BM Galaxies



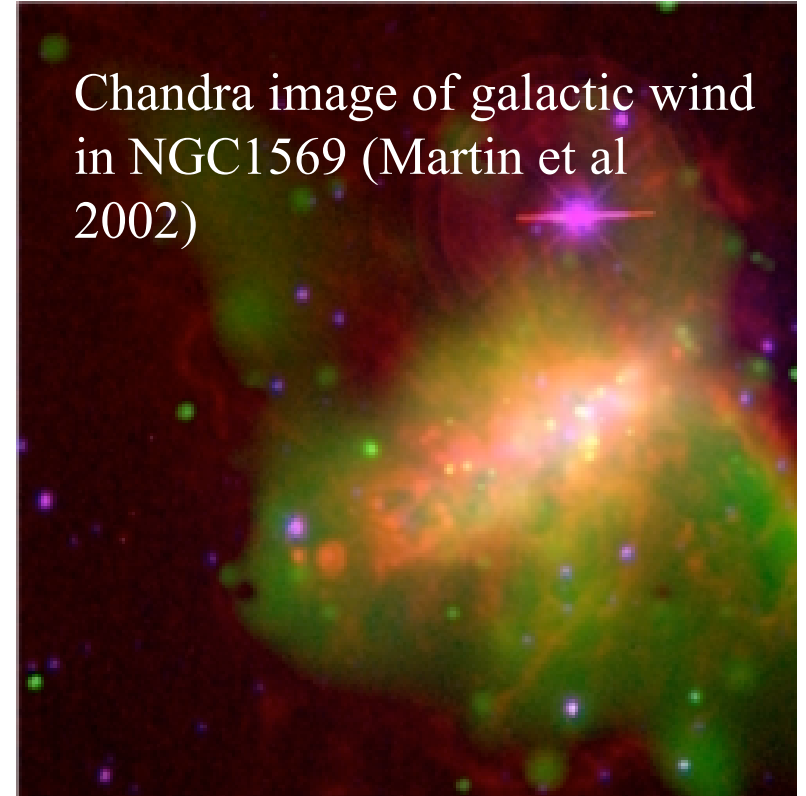
- The kinematics of outflowing ISM gas is similar in  $z \sim 3$  and  $z \sim 2$  star-forming galaxies

- Typical velocities are  $\sim 200$ - $400 \text{ km/s}$  with respect to nebular line redshifts,
- Difference between Ly $\alpha$  emission and interstellar absorption is  $\sim 500$ - $1000 \text{ km/s}$

- If thermalized this corresponds to  $kT \sim 0.4$ - $10 \text{ keV}$

# Origin and Evolution of Galaxies

- Another one of the “big themes”
- Does x-ray astronomy have much to offer?- YES
- Issues of
  - Evolution of SFR with  $z$
  - Where do the metals created in star formation go?
  - Are galactic disks being formed today?
  - What the energy balance in the ISM and how does this effect star formation
  - What is the effect of AGN on the formation and evolution of galaxies and VV what is the effect of galaxies on the AGN
  - How do mergers proceed- role of shocks in galaxy formation
  - What is amount of and distribution of dark matter?
  - Can the history of AGN activity be unraveled
  - Tests of CDM galaxy formation models



ALL of these are big picture issues and have conferences of their own  
Major progress in any of these is important

## ■ CAN WE PROVE ROLE OF AGN FEEDBACK?

- Detailed mapping of region of energy deposition
- Plasma diagnostics (heating, sound/gravity waves)
- Velocities

Begelman 2004

## ■ EFFECTS OF STAR FORMATION

- Abundance maps
- Mixing (high spatial resolution)

## ■ ENERGY TRANSPORT PHYSICS

- Waves, conduction, viscosity
- Bubbles/cavities – contents?
- Effects of magnetic fields and cosmic rays
- Shocks

**All of these tests require high spectral resolution, good spatial resolution and good signal to noise**

# Present status of theory

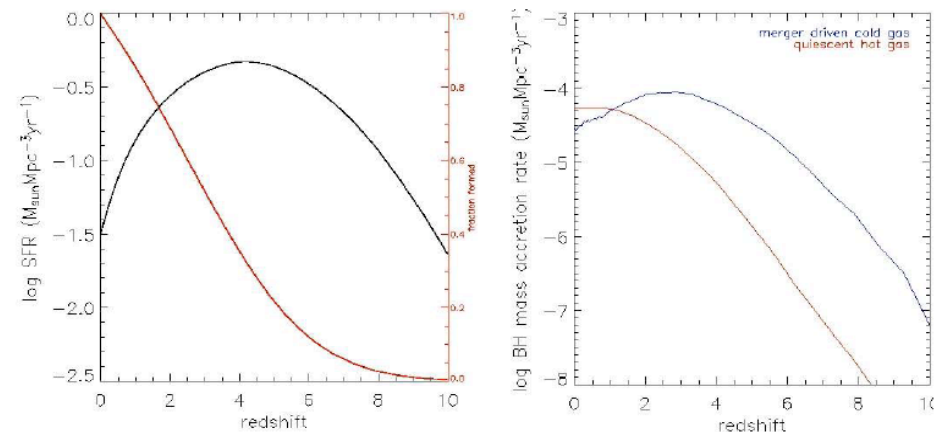
Simon Whit

- Radiation, hydrodynamic and material feedback are all important at some time for the galaxy/IGM interaction
- Many aspects of feedback are too uncertain and too complex to be reliably simulated **Data are critically needed**
- Insertion of simplified models into simulations or semi-analytic treatments remains the only way to gain intuition
- Star-formation related feedback (incl. “quasar-mode” AGN) may be responsible for the faint-end slope of the LF
- Non-star-formation related feedback (“radio mode” AGN?) may be responsible for the exponential cut-off of the LF

# What is required to Constrain these ideas

## Evolution of feedback sources

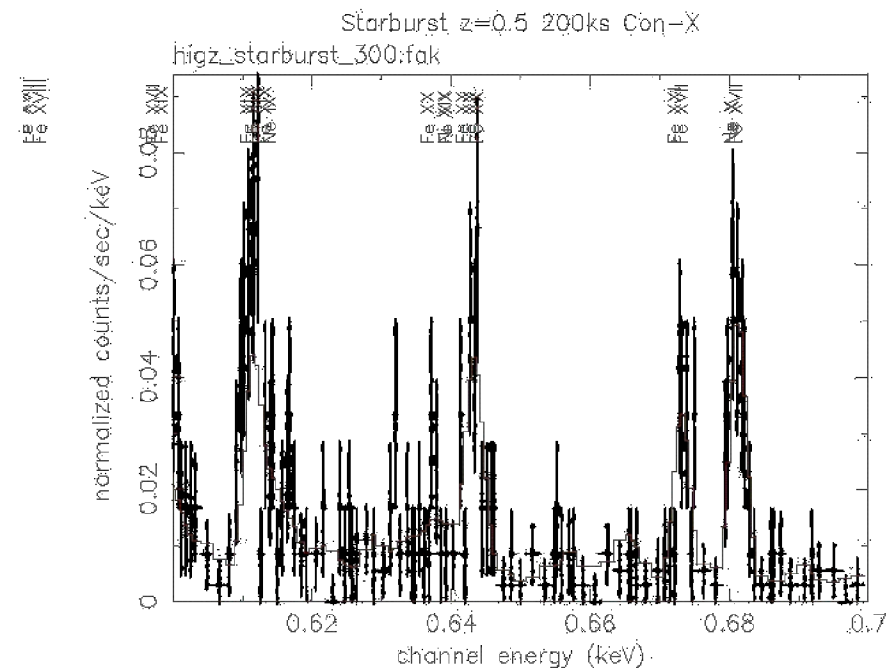
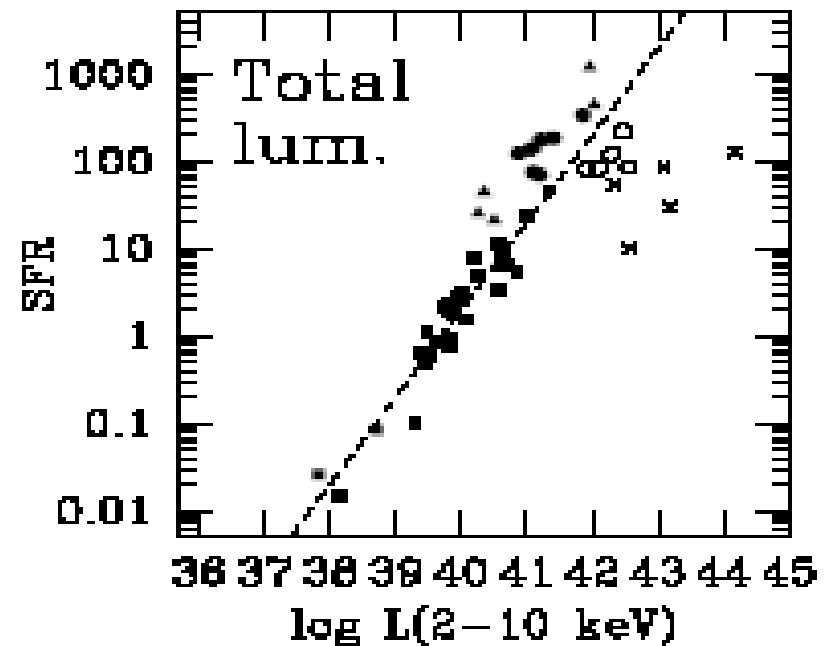
- What is observable to test these ideas? (x= requires x-ray data)
  - x Direct measure of energy injection by radio loud and radio quiet AGN as a function of redshift
  - x Measurement of the effects of the AGN on surrounding gas (e.g. groups and clusters) as a function of redshift
  - x Measurement of the energy and metal input from star formation (e.g. superwinds)
  - Nature of host galaxies with and without AGN
  - x Observe the IGM and determine its metallicity as a function of position and redshift



- AGN have enough “energy” to heat the IGM in groups-  
can produce the  $\sim 1$  keV/particle needed
  - If  $\sim 0.1$  of the radiative energy goes into the wind
- What are the required observations??
  - Do “all” AGN have winds- how much energy is in the winds-
  - how do they evolve
  - Does the evolution of entropy in groups “follow” the AGN evolution??
  - Can one literally “see” the ejection of energy??
    - (Con-X observations of turbulence in groups which have AGN )
- The only way to detect the winds is via high resolution spectra and timing

# What Can Con-X do with respect to Starbursts?

- As shown by many authors  $L(x)_{0.5-2}$  is  $< 10^{42}$  ergs/sec
- **At  $z=0.5$**  this is 0.054 Con-X cts/sec in the calorimeter.-  $10^5$  sec exposures allow some information- however the strongest lines have only 5 photons (!)
  - If the true wind speed is 300 km/sec the error is  $\pm 200$  km/sec
  - At exposures of  $2 \times 10^5$  the situation is much better with  $\pm 90$  km/sec error (4 eV resolution)
  - **Factor of 3 increase in collecting area is very useful**
- **Objects too dim at  $z > 0.7$**  for any reasonable mission- due to low flux and redshifting of signal (e.g. effective temperature at  $z=0.7$  is 0.4 keV) (e.g. Lehmer et al show that at  $z \sim 3$  the U band dropouts are  $\sim 3 \times 10^{-7}$  Chandra cts/sec =  $1.2 \times 10^{-5}$  Con-X cts/sec)
- Objects too small (10kpc) to resolve at  $z > 0.3$  ( $1'' = 8$  kpc,  $z=0.7$ )

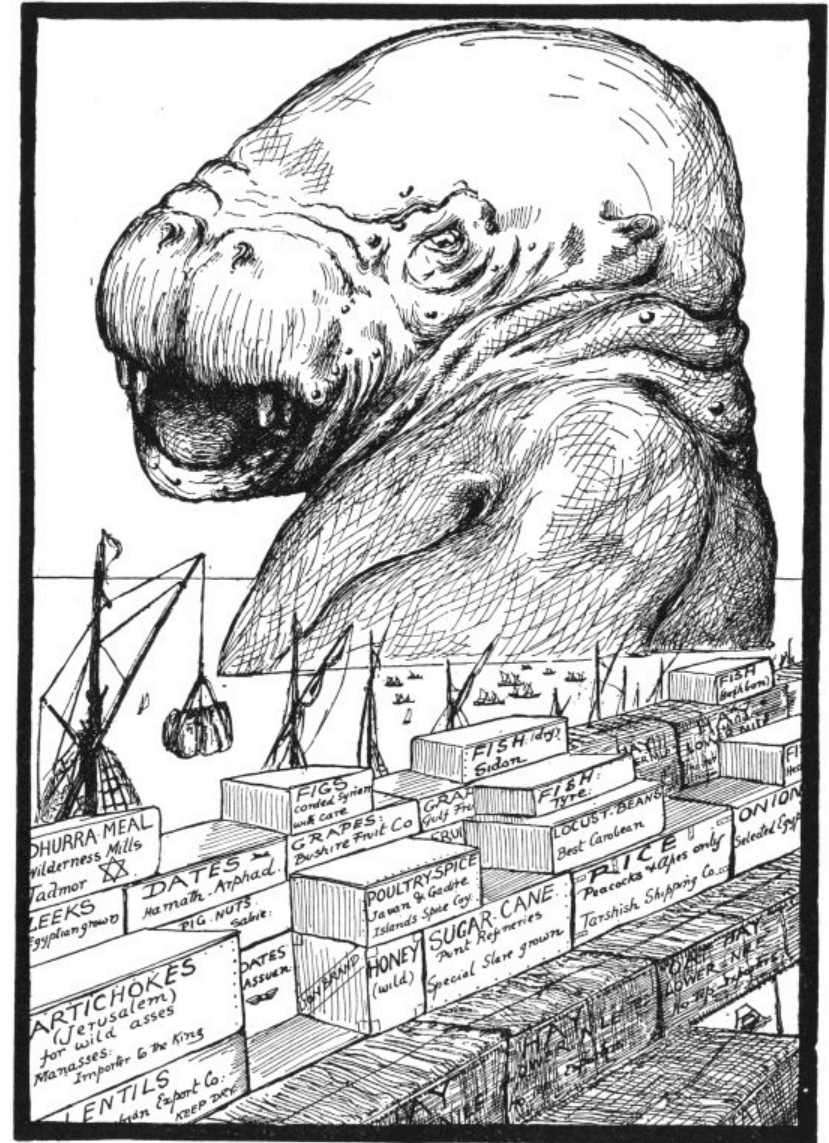


# Mission requirements

- Sufficient spectral resolution to measure winds in AGN and starburst galaxies and turbulence in groups  $>400\text{km/sec}$ - 2 eV at 600 eV
- Sufficient sensitivity to measure reasonable samples of these objects  
Starbursts to  $z\sim 0.7$  'ok' with 3x Con-X area

Scaling from Chandra 300ks observations of bright AGN one needs  $2 \times 10^6$  secs with Con-X area at  $1 \times 10^{-14}$  ergs/cm<sup>2</sup>/sec for AGN winds

- Sufficient angular resolution to locate turbulence/mass motion in ‘nearby’ groups clusters 5”
- Low enough background to measure winds and surface brightness of groups



THIS is the picture of the Animal that came out of the sea and ate up all the food that Suleiman-bin-Daoud had made ready for all the animals, in all the world.

# Structure and Evolution Mission

## Requirements- Top Priority

- **Spectral resolution**

Need calorimeter resolution to measure the metallicity precisely, determine dynamical state of the gas in AGN, star forming galaxies, groups and clusters.

- 4 eV is adequate for  $E > 1$  keV, need 2 eV at lower energies .

- **Effective area**

- starbursts at  $z > 0.3$
- abundance measurements and dynamics of groups
- AGN exposure time for objects at  $10^{-14}$  (sources of x-ray background)

- **Field of View-**

- Groups are large at  $z < 0.5$ , galaxies at  $z < 0.05$ , galactic winds  $> 10'$  at low  $z$ ; need  $> 2'$  FOV
- Number of sources in beam for AGN winds

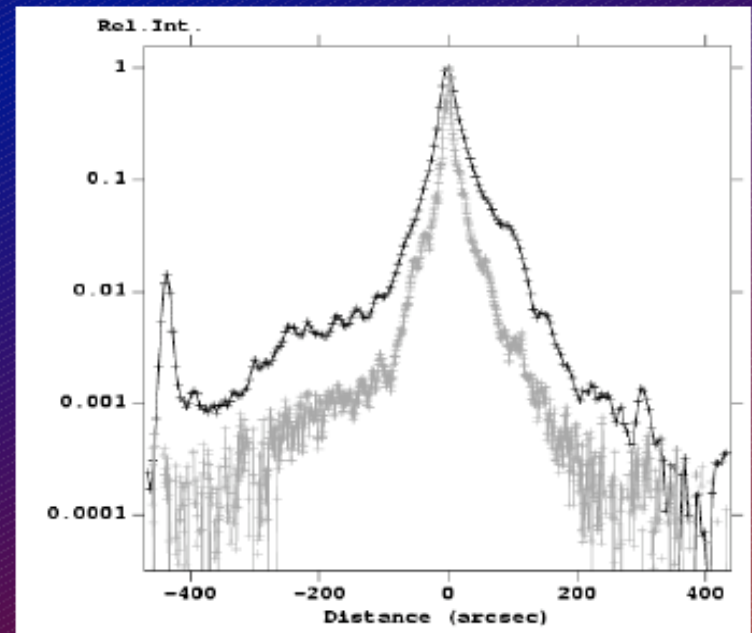
- **Background** - outer regions of starburst where wind is dominant have low surface brightness-

Chandra image of galactic wind in NGC1569 (Martin et al 2002)



Right: Surface brightness, X-ray and H $\alpha$  emission

M82-800'' in size;



## Mission Requirements- Lesser Priority

- **Angular resolution-**

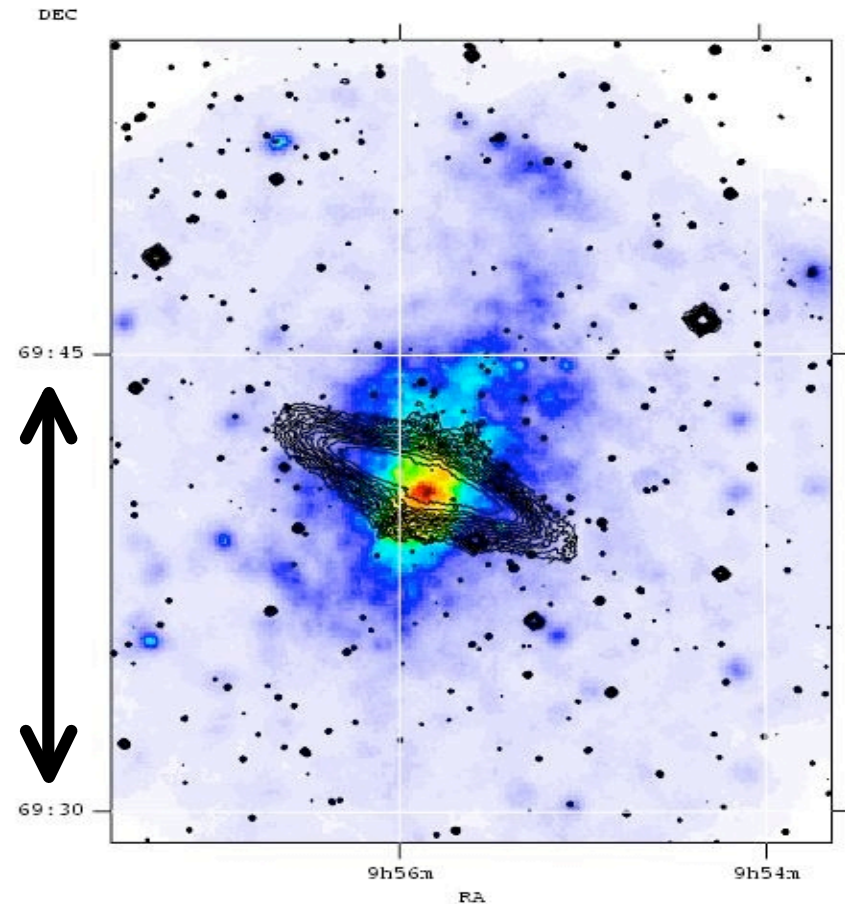
Galaxies are complex- but outer wind regions are not strongly contaminated by point sources

15'' is adequate at low  $z$  to measure winds to directly measure dynamics near central AGN or structure at higher  $z$ , 15'' is not good enough, further work required

- **Bandpass**

- Must observe, wide range of temperatures
- Response from 0.3- 12 keV to get direct measures of AGN over wide redshift range

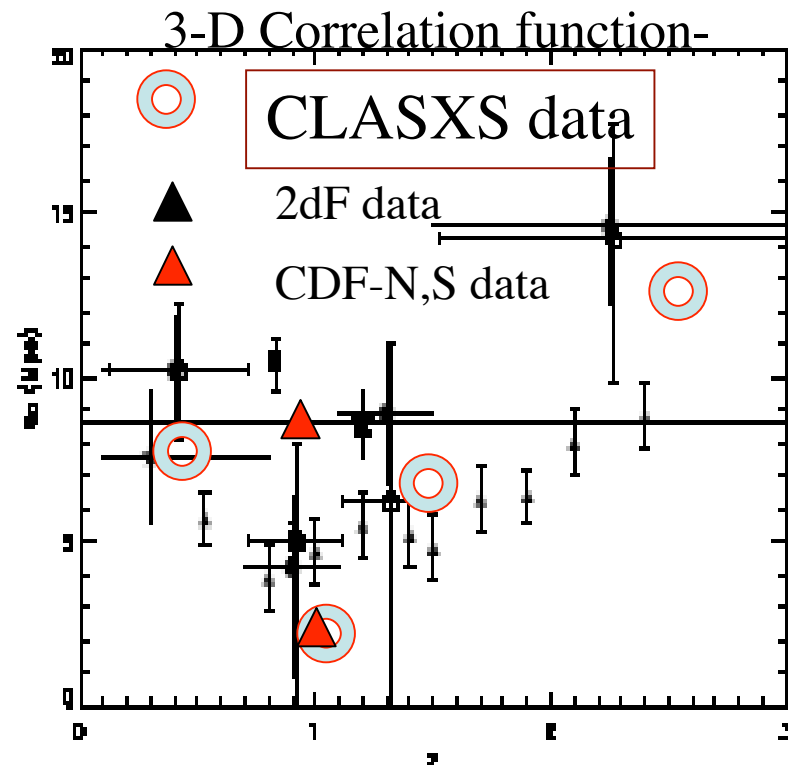
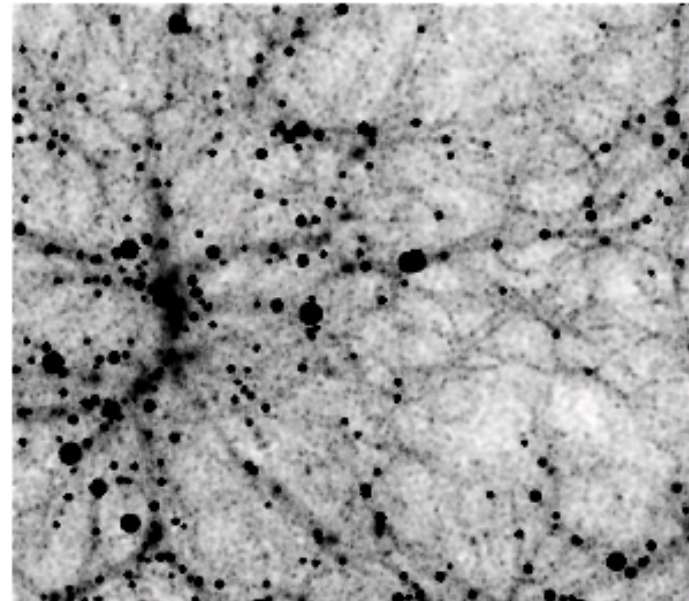
M82 XMM OVIII image



15' (7.3'' at  $z=0.1$ )  
10'' = 44 kpc,  $z=0.3$

# Correlation Function of Tracers

- The correlation function of various tracers (AGN, galaxies, groups, clusters) is related to their relation to their mass
- AGN can be studied out to very high  $z$ , their redshifts will be determined from the x-ray data themselves (enormous saving of 8-10 m optical telescope time)
- The much higher areal density of x-ray selected AGN ( $\sim 300/\text{sq deg}$  at  $10^{-14}$  ergs/cm<sup>2</sup>/sec) allows the correlation function to be determined from a fairly small solid angle (1-2 sq degree)



# Drivers for Correlation Function Science

- To do correlation function need **a large area over a wide range in solid angle**.
- Need **calorimeter resolution to get precise redshifts with small number of photons** (at 300 srcs/degree<sup>2</sup>-4 arc min radius to get 4 srcs)
- Con-X just marginal for 10<sup>5</sup> sec exposure at  $F(x)=1 \times 10^{-14}$  (sources of x-ray background) - narrow line is just 3 $\sigma$ - broad line needs better S/N also

Con-X simulation of a 'typical' AGN  
 $z=1$ ,  $F(x) \sim 10^{-14}$

EW of narrow(1000km/sec) line 85 eV

Error in redshift is 0.007 -

3x area -smaller errors in  $z \pm 0.004$

with (line is resolved with

$\sigma=400$ km/sec) broad line significant

and width determined

